XN-JUB-82-86

GROUND WATER QUALITY AND FLOW CHARACTERISTICS IN THE VICINITY OF THE EXXON NUCLEAR COMPANY, INC. FUEL FABRICATION FACILITY RICHLAND, WASHINGTON

OCTOBER 1982

RICHLAND, WA 99352

EXXON NUCLEAR COMPANY, Inc.

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EXECUTIVE SUMMARY

A plume of groundwater containing elevated concentrations of NH_3+NO_3-N, fluoride and sulfate currently exists near the Fuel Fabrication Facility of Exxon Nuclear Company, Inc. of Richland, Washington. Groundwater analysis indicates the plume to presently extend 500-600 feet laterally, 1000-1100 feet horizontally and 40-50 feet vertically. This plume is travelling in a northeast direction, toward the Columbia River, at a rate of about 100 ft/year with arrival at the river predicted to occur within approximately 75 years.

The impacts of this plume upon the area appear to be relatively minor. Due to the current and future land use in this region, namely nuclear energy research and development by the Department of Energy, it is not anticipated that the aquifer within the region of the plume will be utilized during this time period for either agricultural uses or human consumption. Additionally, the water quality of the Columbia River will not be adversely affected by the components of the plume due to the large assimilative capacity of the river.

INTRODUCTION

Exxon Nuclear Company, Inc. currently operates a Fuel Fabrication Facility in Richland, Washington (see Fig. 1). As part of this operation, the firm maintains several ~~process~~ chemical waste storage lagoons at the site. These lagoons receive process wastes which contain appreciable levels of dissolved ammonia, sulfate, fluoride, and, to a lesser extent, nitrate. In the past some leakage from these lagoons has created a chemically contaminated plume within the groundwater, as evidenced by water quality samples obtained from monitoring wells at the facility.

The objective of this report is to determine the current boundaries of this plume, and to project its progress to the Columbia River. To accomplish this, the characteristics and properties of the groundwater in the vicinity of the Exxon site were investigated.

DIRECTION OF GROUNDWATER FLOW

The Exxon site is located adjacent to the southeastern boundary of the Hanford Reservation, an area operated by the Department of Energy engaged in nuclear energy development. Because of the long history of nuclear energy in the area, extensive groundwater evaluations have been conducted previously, and a good hydrologic data-base now exists for the region.(1) (2) A regional water table map is presented in Figure 1, and indicates that in general, flow is towards the Columbia River. In the southeastern portion of the area, the groundwater is influenced by recharge from the Yakima River(3), resulting in the groundwater flow lines travelling in a northeasterly direction (flow lines are perpindicular to contour lines) in the vicinity of the Exxon site.

Current well-level data from Exxon wells and those located around the Pacific Northwest Laboratories of Battelle Memorial Institute confirm this northeasterly flow (see Fig. 2).

To determine more accurately the direction of groundwater movement directly beneath the Exxon site, water level data obtained from a network of monitoring wells maintained by Exxon were plotted for selected periods within the last five years (see Figs. 3-7).

In 1977, the Exxon groundwater monitoring network consisted of eight (8) wells. By 1982, the network had been expanded to 15, resulting in more data points for Figs. 4-7 than are present in Figure 3.

The flow in the direct vicinity of the lagoons was almost due-north in 1977, especially at the north end of lagoon #1, as evidenced by Fig. 3. The data does indicate however, that the

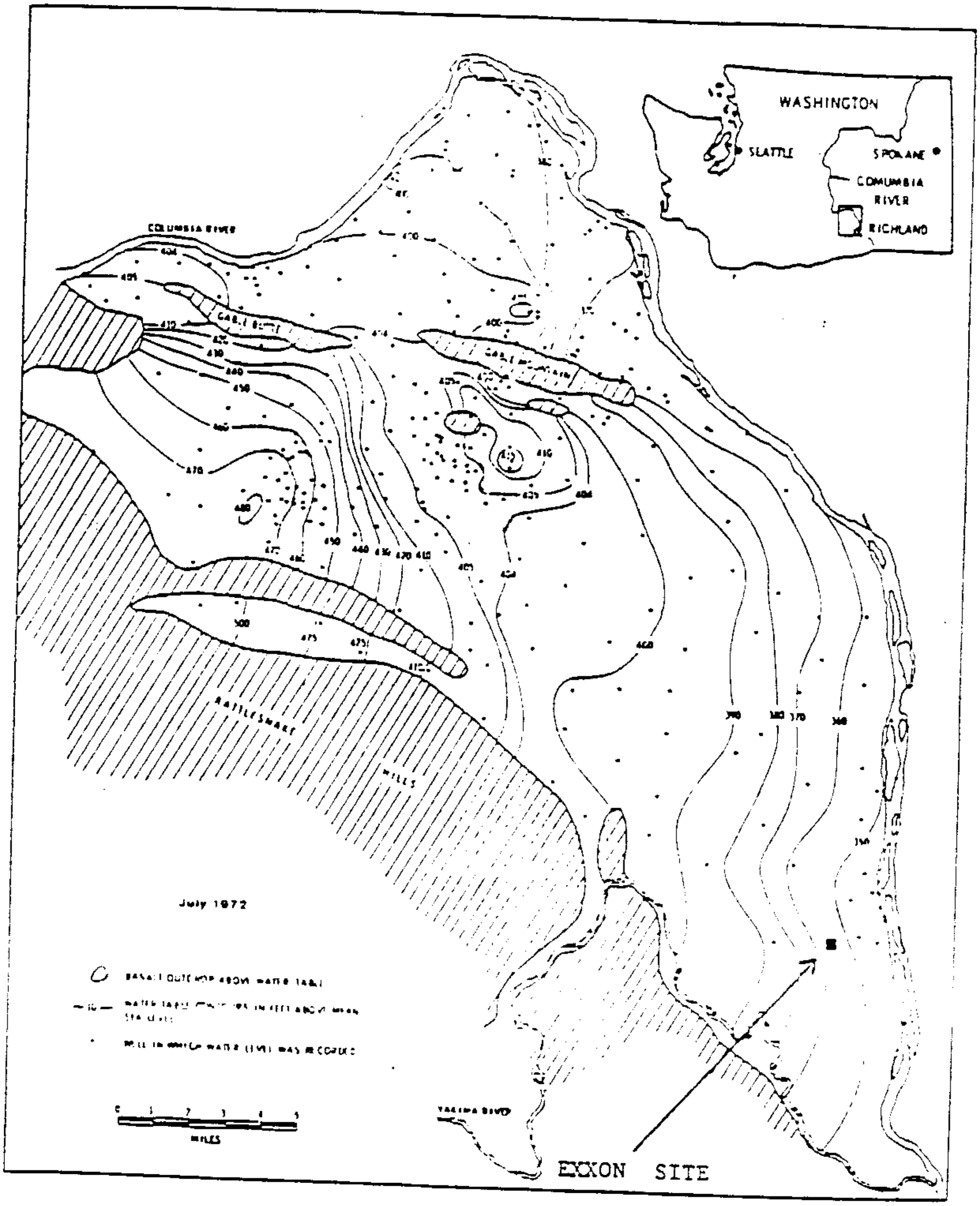

FIGURE 1

Hanford Site Water Table Map (after Lindberg & Bond 1979)

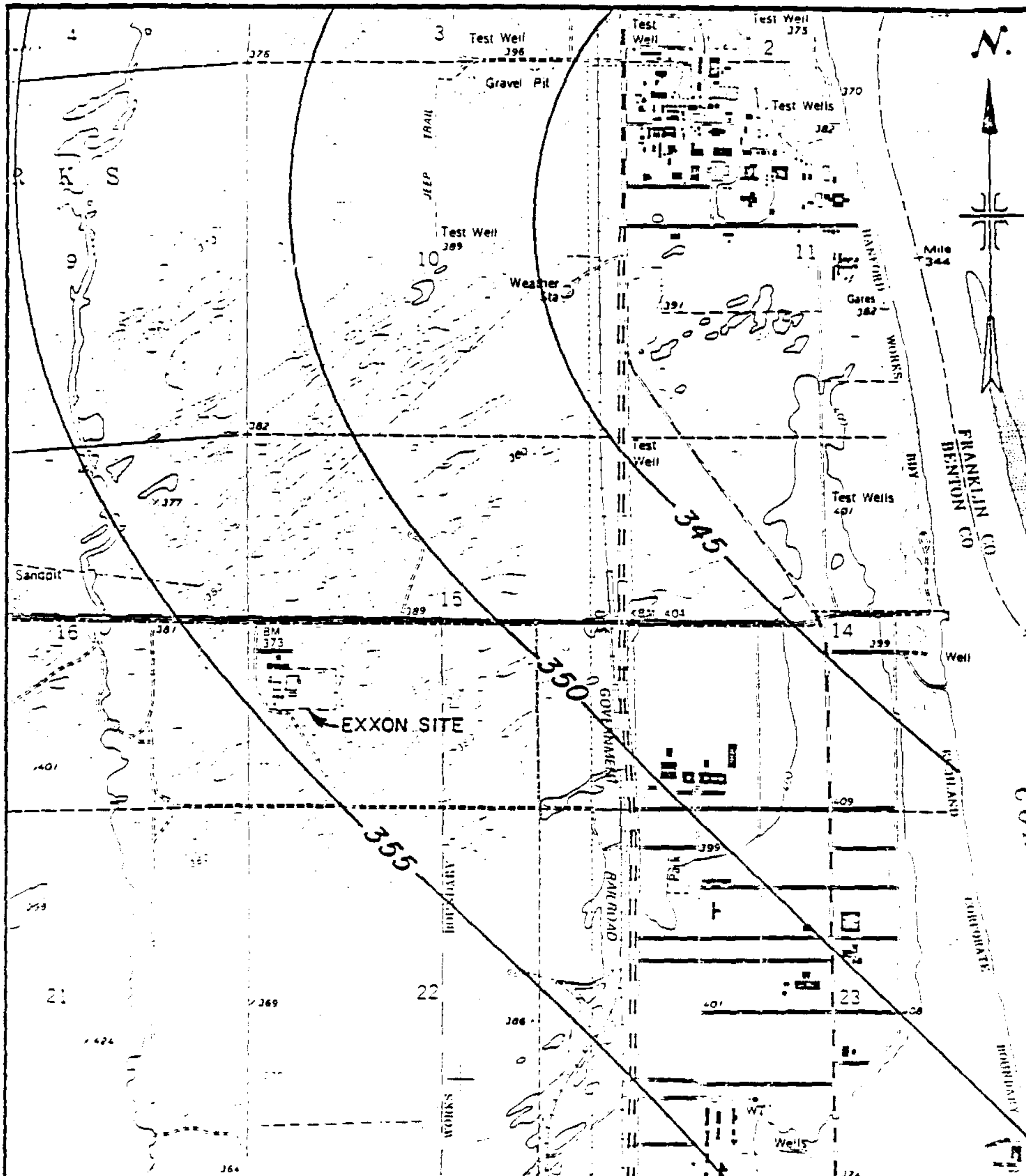

FIGURE 2
SITE WATER TABLE MAP
EXXON NUCLEAR COMPANY

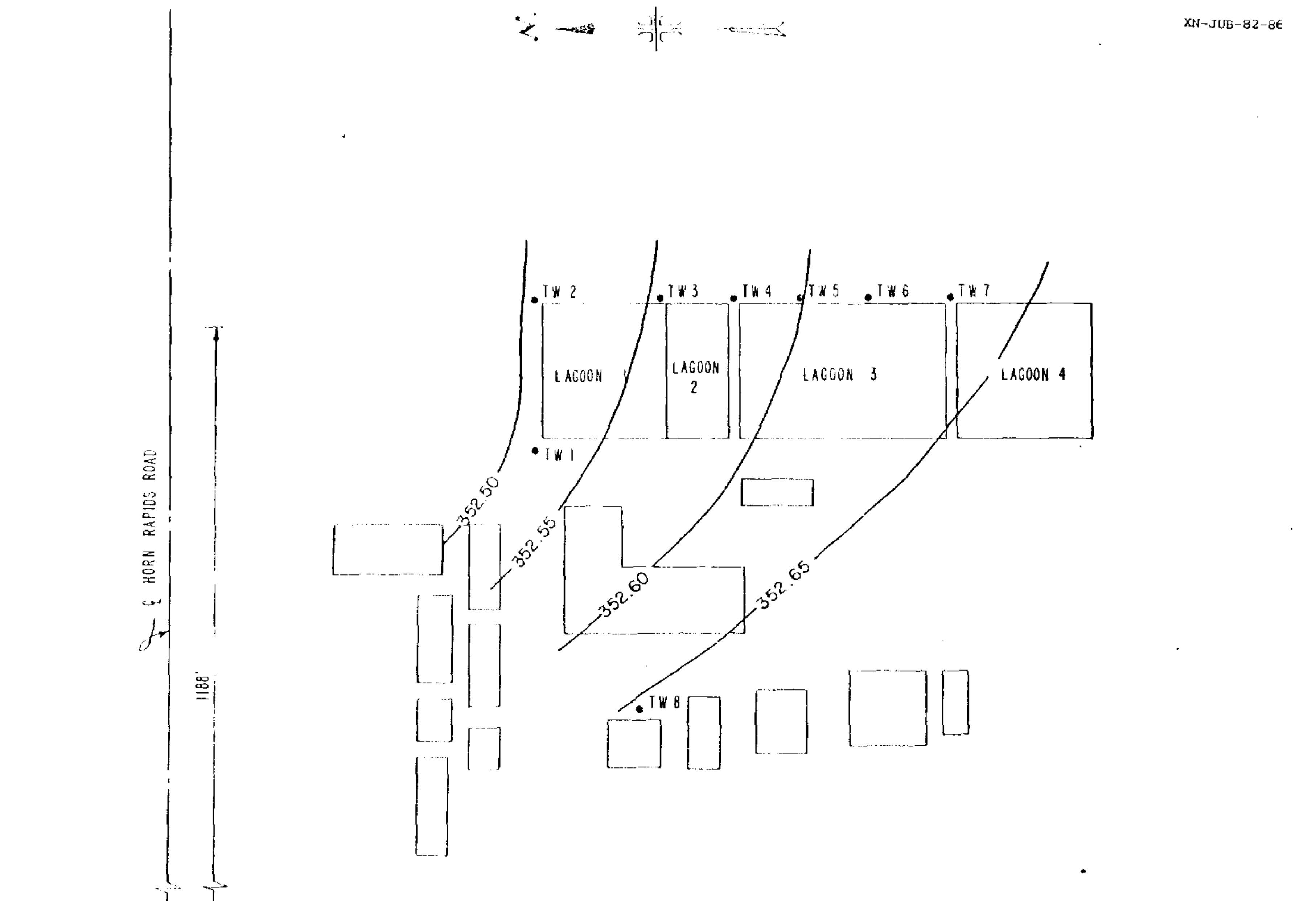

FIGURE 3
GROUNDWATER CONTOURS IN THE VICINITY
OF THE WASTE LAGOONS
EXXON NUCLEAR COMPANY
JUNE, 1977

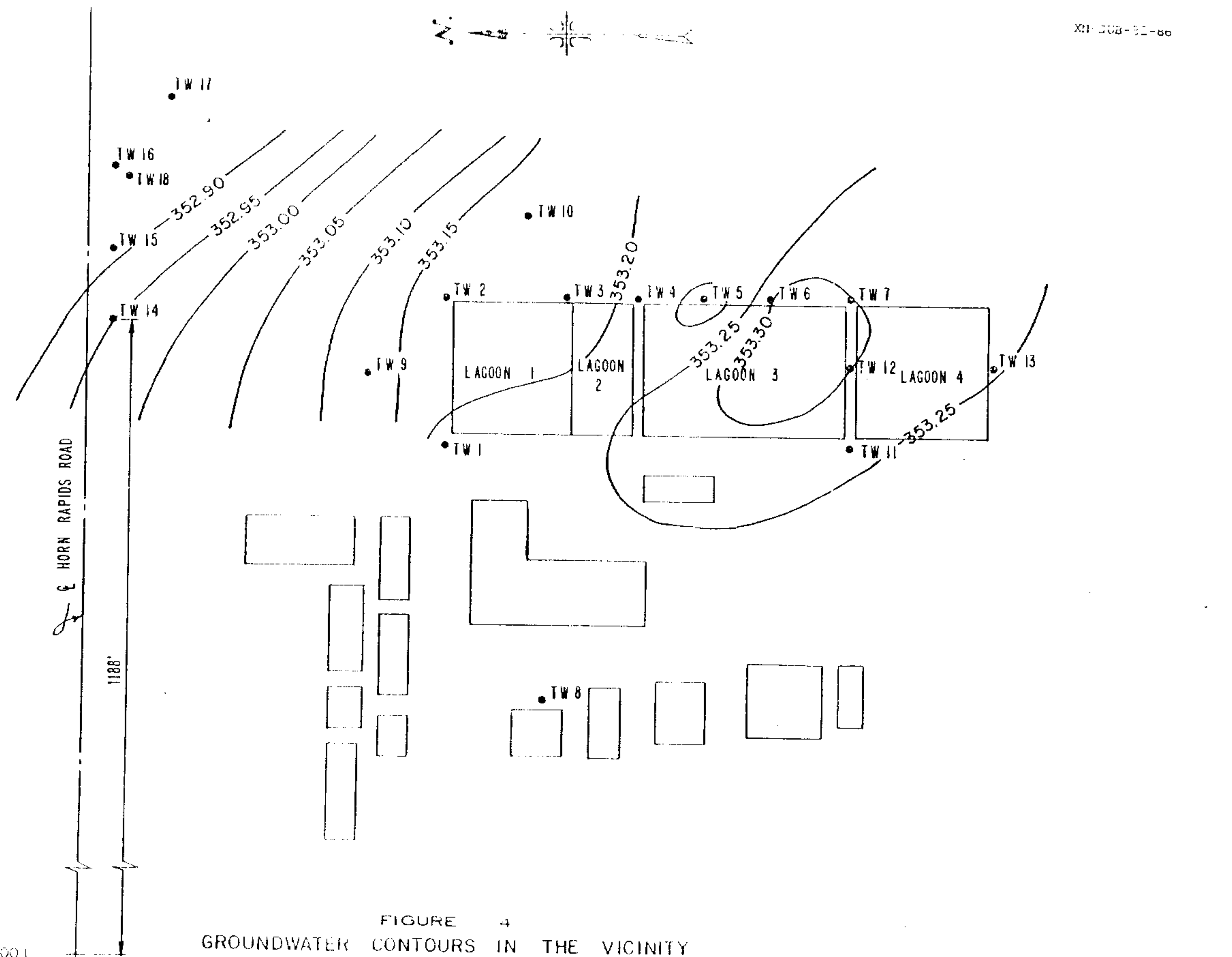

FIGURE 4
GROUNDWATER CONTOURS IN THE VICINITY
OF THE WASTE LAGOONS
EXXON NUCLEAR COMPANY
JAN., 1981

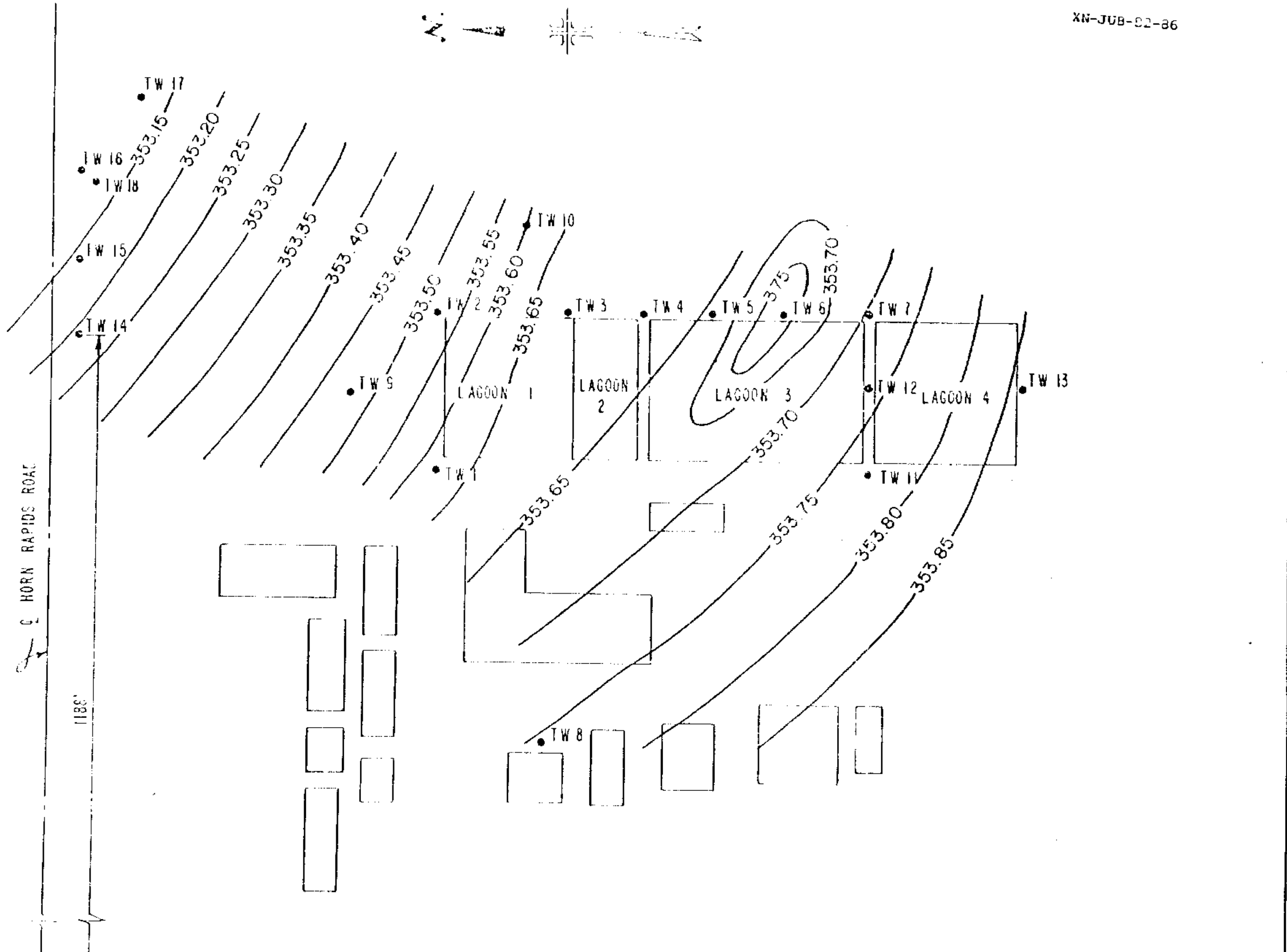

FIGURE 5
GROUNDWATER CONTOURS IN THE VICINITY
OF THE WASTE LAGOONS
EXXON NUCLEAR COMPANY
MAY, 1981

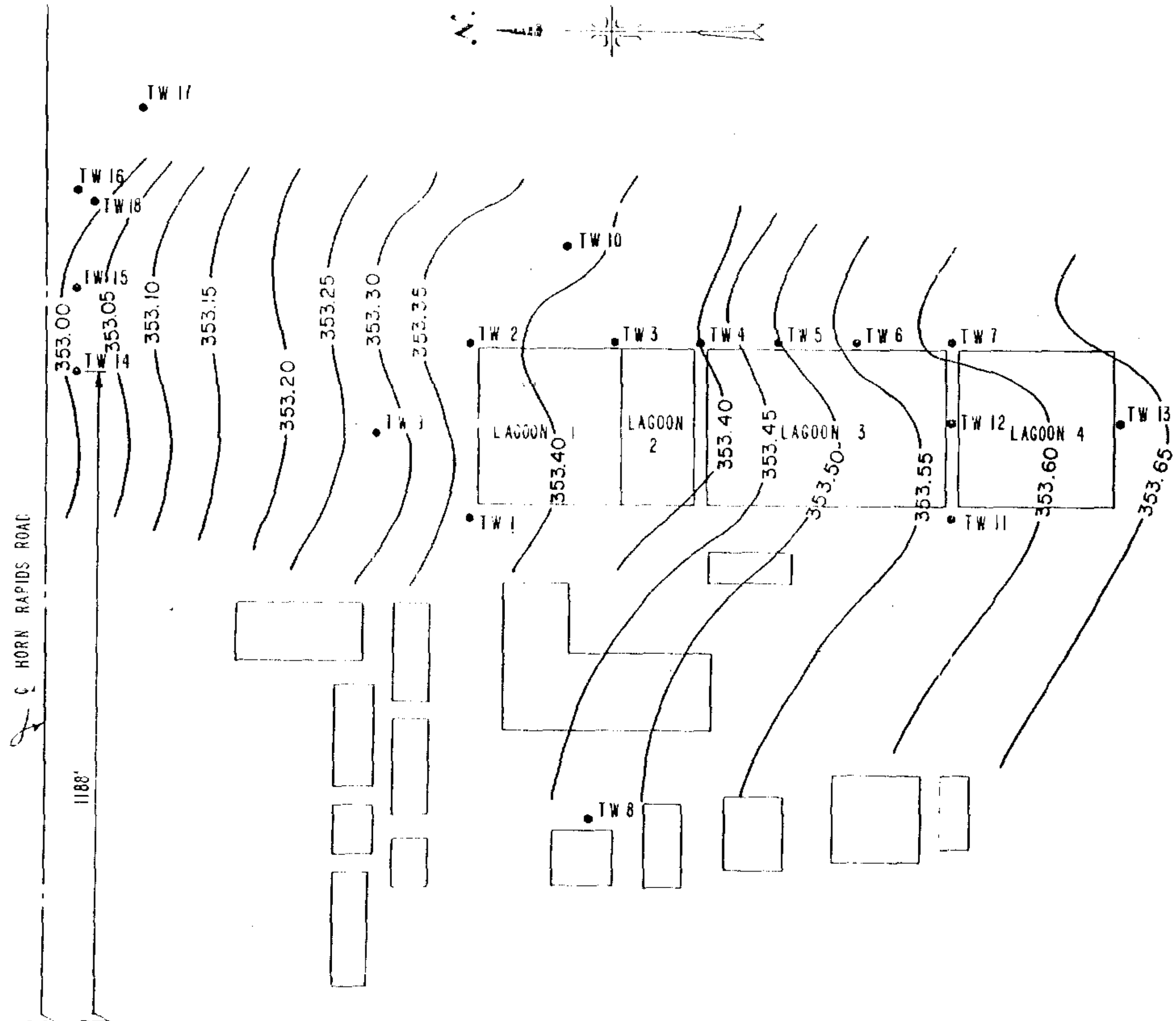

FIGURE 6
GROUNDWATER CONTOURS IN THE VICINITY
OF THE WASTE LAGOONS
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OCTOBER, 1981

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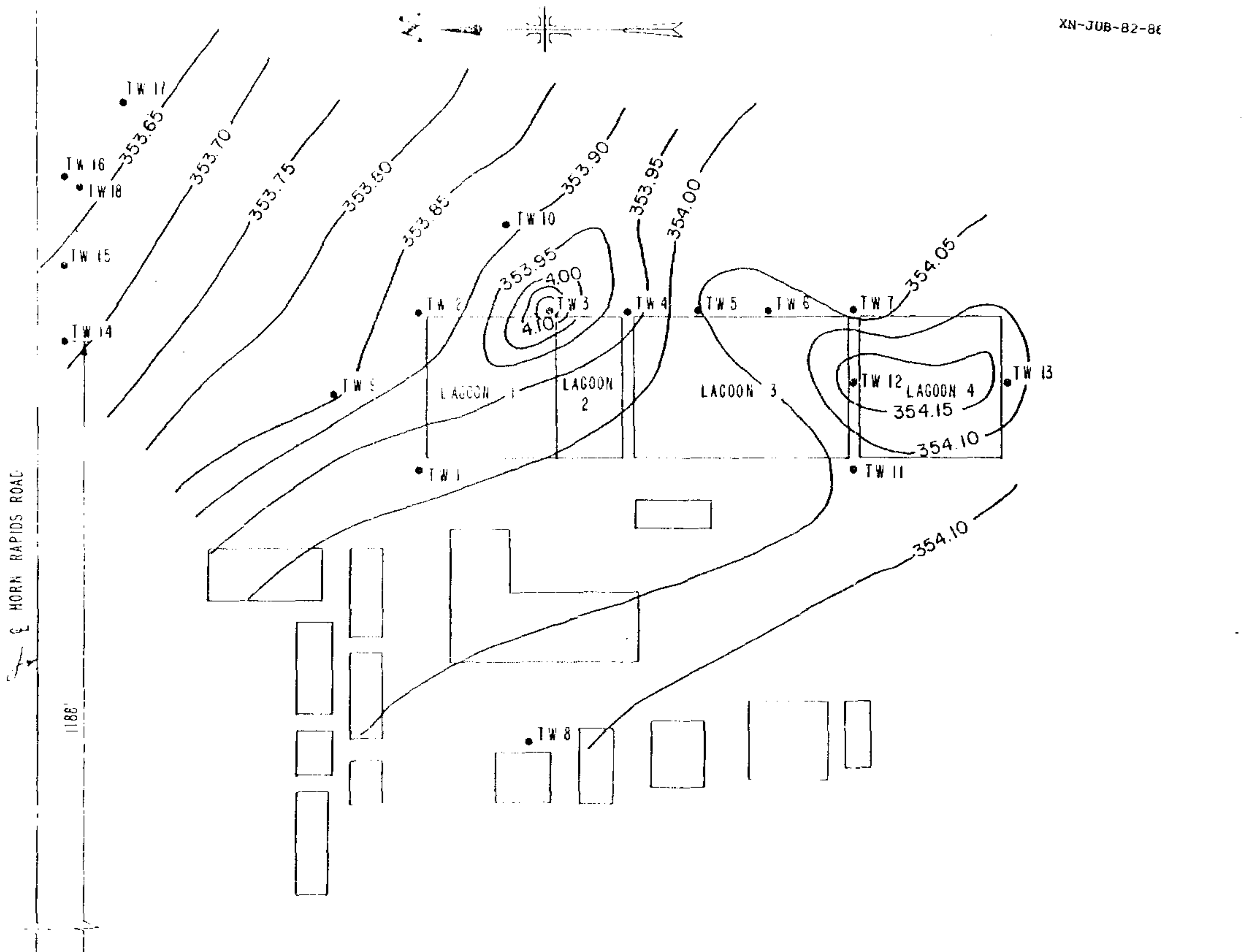

FIGURE 7
GROUNDWATER CONTOURS IN THE VICINITY
OF THE WASTE LAGOONS
EXXON NUCLEAR COMPANY
MAY, 1982

more typical northeast flow pattern was also present to the west of the lagoons at this time. By 1981 the flow beneath the lagoons had shifted more to the east, resulting in a northeasterly flow under the entire Exxon site (see Figs. 5&6). This same orientation of flow lines was demonstrated in 1982 as well, but with several apparent alterations (see Fig. 7).

The most obvious progression which one notices when viewing these contour maps chronologically is the development of "plateaus" and "mounds" of groundwater directly below the lagoons. In 1981 there was a small mound present around test well 6, with a fairly broad plateau under lagoons 2 & 3 (see Fig. 5). (Figures 4, 5 and 6 represent winter, spring, and fall conditions respectively in 1981.) By 1982, a mound had developed in the region of TW 3 which was about 0.16' higher than the surrounding area with a second, smaller mound beneath all of lagoon 4. This mound had also developed a lobe which expanded along the direction of flow (see Fig. 7).

This development of mounds and plateaus could appear to be indicative of leakage from the lagoon area. A leak in the area of the mounds, as seen in Figs. 5-7, would have been detected by water quality data for these wells, given the predominant direction of flow at this time. From the data presented in Appendix IA, wells 4 and 6 generally exhibit levels of NO_3 + NH_3 - N in the range of 10-20 ppm, which is higher than the 1-2 ppm found in the control well #8. Well #5, however, which is located directly between wells 4 and 6, shows no nitrogen contamination over that of background levels. In addition, neither sulfate nor fluoride contamination (above ambient levels) have occurred in any of these three wells (see Appendix IA).

A second, somewhat more feasible explanation for the development of the mounds can be determined by observing a second chronological progression in the groundwater elevations. Figure 5, drawn for May 1981, indicates a broad plateau region below the lagoons with a slight mound near the east side of Lagoon 3. At this time the water table elevation at the control well (#8) was 353.76'.

Figure 6, drawn for October 1981, indicates the plateau to be diminished greatly while the mounds have completely dissipated. The elevation at well 8 at this time was 353.47'. Levels had dropped (with respect to May 1981) in virtually every other Exxon well also, indicating a general drop in the water table in the area, as would be expected in October.

In Figure 7, drawn for May 1982, the mounds and lobes had redeveloped and intensified over those in 1981. The elevation in TW 8 was 354.07' at this time, while every other Exxon well also exhibited levels greater than those in January or May of 1981.

The implication of this progression is that the mounds and plateaus appear to be dependent upon the water table levels of the area in general, which are seasonally influenced.

A logical explanation for these anomalous mounds, in light of this seasonal variation, would be that as the water table rises in the spring and early summer, the groundwater directly below the lagoons encounters soil which has been disturbed in some manner by the physical placement of the lagoons. As a result of this disturbance, the soil-moisture characteristics of the soil could have been altered so as to create a greater capillary "pull" in this region.

The elevation of the bottom of lagoon 4 is 361.5', under which is a six inch layer of sand positioned between two impervious liners. The groundwater mound elevation under lagoon 4 in May 1982 was 354.18', which means the groundwater was within seven feet of the top liner in the lagoon, while it was probably within 2-3 feet of an area exposed or disturbed during construction.

The placement of an impervious layer (lagoon liners) below the lagoons would serve as a barrier to natural percolation as well as leakage from the lagoons. This would decrease soil moisture in this area with time. In addition, the added load on this soil, as a result of the weight of the wastewater above, would compact the soil somewhat causing an increased capillary capability. The result of these two factors appears to have been to increase the moisture "drawing" and retention capabilities of this disturbed soil area, resulting in the development of groundwater mounds and plateaus.

The fact that well 5 did not exhibit increased levels of nitrogen while wells 4 and 6 did can be explained by possible leaching of small, isolated areas of leaked material which did not percolate down to the groundwater. As the water table rose, it would have encountered these contaminated soils, resulting in a release of $NO_3 + NH_3 - N$ to the groundwater (Figures 3-7 indicate a rising trend in groundwater levels in this area).

The existance of such isolated areas could also explain the fairly consistant levels of these contaminants in wells 2 and 9. Examination of Appendix IB indicates that nitrogen (as well as sulfate and fluoride) levels have not dropped significantly, as would be expected with the cessation of leakage. Rising groundwater levels, encountering contaminated soil above, could leach previously unreleased material, accounting for the observed chemical levels at these wells.

HYDROGEOLOGY OF THE EXXON SITE

Previous hydrogeologic studies of the Hanford area have found the region to be largely dominated by the Pasco gravels and the Ringold Formation(1)(2). Both of these strata were deposited as sediments of the ancestral Columbia River. The Ringold formation can consist of two subgroups, one composed of sand and gravel, while the second consists of sands and silts with some clay. The area is underlain by the Columbia River Basalt group.

Drilling logs of Wells 16, 17, and 18 indicate the presence of the Pasco gravels (along with eolian sand deposits) from the surface to a depth of about 18 feet. Sand and gravels of the Ringold formation occur below this to about 43 feet, at which point a layer of impervious silt and clay (also of the Ringold formation) extends for at least 17 feet. Drilling was stopped at 60 feet on Well 16 when it was determined that this impervious silt and clay layer was not simply an isolated lens. Data exists which implies that this silt layer is anywhere from 20-40 feet thick[1]. Below this layer is about 100 feet of sand and gravel underlain by a second layer of impervious silt and clay, approximately 20-40 feet thick. Below this lies the Columbia River Basalt group.

Onsite monitoring wells indicate the water table is presently located in the Ringold formation, with a static level of about 20-25 feet below the surface (at Wells 14-18). This unconfined acquifer has a lower boundary elevation of about 332' at this location, which is formed by the impervious silt and clay layer.

RATE OF GROUNDWATER FLOW

To determine the rate at which the groundwater is travelling away from the plant site, a pump test was performed utilizing TW 16 as the pumping well and Wells 17 and 18 as observation wells. The test was conducted for four hours, after which time the well levels stabilized. The data for this test, as well as calculations used in data reduction, are included in Appendix II.

Test well 16 is cased with 6" diameter steel casing to a depth of 33 feet, with a five foot section of stainless steel Johnson well screen extending to 38 feet (the total depth of the well). Wells 17 and 18 are both 3" PVC, cased to a depth of 37 feet. Both wells are slotted from 24 to 28 feet and again from 33 to 37 feet, representing the top and the bottom of the saturated layer, respectively.

From the information generated by the pump test data, a permeability of 3,029 gals/day/ft^2 was calculated for the aquifer perpindicular to the flow while a value of 4,728 gals/day/ft^2 was calculated parallel to the flow. (Permeability is simply the amount of water which would flow through a 1 ft^2 "window", or section of the aquifer in a day.)

In general, this would indicate that under the same conditions of hydraulic gradient, the aquifer would be more permeable in the direction of flow than laterally. Permeability is a highly variable component of the aquifer, however, and it would be best to combine these two values for a mean value for permeability of about 3,900 gals/day/ft^2 in describing the aquifer.

The velocity of the groundwater through the aquifer is the product of the permeability and the hydraulic gradient (the slope of the water table surface). Thus, if the gradient changes, so will the velocity, (ie: the steeper the gradient the greater the velocity). Figures 4-8 illustrate the changes in gradient from 1977 through 1982. The gradient in 1977 was 0.00038 ft/ft (Fig. 3) while in May of 1981 it was 0.00074 ft/ft (Fig. 5). (Contour lines closer together indicate a higher gradient.) These values result in velocities of about 72 ft/year in 1977 and over 140 ft.year in 1981.

By using the highest of the permeability and gradient factors, a maximum velocity is calculated at about 170 ft/year, while use of the lowest values yields a minimum velocity of about 56 ft/year. A reasonable yearly average, based upon available information, would be 100 ft/year.

HISTORICAL GROUNDWATER QUALITY IN THE VICINITY OF EXXON NUCLEAR

Water samples from the monitoring network of wells have been analyzed on a monthly basis since 1973. Routine analysis have been for nitrogen (as NH_3 + NO_3), fluoride and sulfate. Exxon has been continually upgrading the monitoring network by periodically installing new wells at strategic locations. Wells 1,2,3,4, &8 have been analyzed since 1973, with 5,6,&7 being added in 1974. Wells 9,10,&11 were added in 1978 and 12&13 were added in 1979. In 1980, wells 14&15 were added to the sampling network and 16,17 and 18 were installed in 1982.

In analyzing the data from this sampling network, a series of trends appears in the levels of the chemical constituents. Wells 5,6,7,8,10,11,12,&13 have not shown any appreciable chemical contamination throughout the period of analysis, while wells 1,2,3,9,14 & 15 all contain/have contained chemicals at levels above recommended drinking water standards. This configuration of contaminated wells indicates that a leak (or leaks) have occurred below lagoons 1 or 2. Groundwater quality data supporting this conclusion are presented in Appendix IB.

It would appear that two occurrences of leakage have developed since the lagoons have been in operation. The first, in mid 1973, was most likely from the north end of lagoon #1, and is identified by a rapid rise in all constituent levels in well #2. Well #1 exhibited a gradual increase in nitrogen levels while no increase was noted in sulfate or fluoride concentrations. Nitrate, which is more mobile than the other constituents, probably reached well #1 by lateral diffusion, accounting for the gradual increase in concentration at this well. Well #3 showed no contamination at this time. These data implicate the north end of the lagoon as the origin of the leak.

When well #9 was first sampled in 1978, it contained chemical contaminants at approximately the same levels as did well #2 at that time, which is reasonable in that it is located directly in the path of the plume. Wells #14 & 15 showed approximately the same chemical contamination levels when they were first sampled in 1980. Well #10 showed no contamination, further confirming the north end of lagoon #1 as the source.

An analysis of rate of travel of the groundwater, based upon time-of-arrival of these chemical constituents at well #14 indicates a minimum velocity of about 100 ft/year, which is consistant with the figures arrived at via the pump test and hydraulic gradient data.

Evidence exists in support of a second leak in 1976, based upon data from wells 1,2&3, presented in Appendix IB.. Well #3 showed a spike in both nitrogen and sulfate during this time while wells #1&2 both showed significant increases in fluoride, sulfate and nitrogen in 1977. As the flow was almost exclusively to the north in the immediate vicinity of the lagoons at this time (Fig. 4), one can see that in order for well #3 to be affected, the source must have been from lagoon #2 since Well #4 showed no contamination. This would also put wells #1&2 in the flow path of this plume, accounting for their elevated concentrations.

CURRENT GROUNDWATER QUALITY IN THE VICINITY OF EXXON NUCLEAR

Wells 1,2,9,14 and 15 (which have been identified as currently being contaminated), were sampled in August 1982, in addition to the three new wells (16,17,18). The results of this sampling effort are presented in Table 1, along with the Federal drinking water standards and values for TW 8, the control well. From this data it is clearly seen that these wells, directly to the north and northeast of the lagoons contain these constituents at levels greater than both the control well and the drinking water standards maximum limits.

One exception is well 17, which exhibits NH_3 levels significantly lower than those of the contaminated wells. Nitrate levels are considerably less also, and are very close to meeting the drinking water standards. Fluoride and sulfate concentrations are also significantly lower, being at levels below the standards set for drinking water. When compared to the control well, however, well 17 does exhibit some evidence of contamination. The remaining wells, (those not listed in Table 1) currently show no appreciable levels of contamination.

KNOWN DISTRIBUTION OF CONTAMINANT PLUME WITHIN EXXON BOUNDARIES

From the lack of appreciable levels of chemical constituents in wells 3 and 4, (wells 1 and 2 are considerably higher) it can be concluded that the southern extent of the plume is below

TABLE 1

Recent Groundwater Data for Contaminated Wells

mg/l

Well	NH_3	NO_3	NH_3+NH_3-N	F	SO_4
1	34	70.0	104	8.7	150
	34	70.0	104	8.3	150
2	55	37.5	92.5	8.8	89
	54	37.5	91.5	8.9	89
9	127	63.1	190.1	16.9	423
	127	62.5	189.5	17.0	423
14	38	62.5	100.5	15.7	303
	38	63.1	101.1	15.6	303
15	78	57.5	135.5	14.0	305
	81	57.5	138.5	14.0	305
16	26	42.5	68.5	5.3	104
	26	42.0	68.5	5.3	104
17 top	0.6	11.6	11.2	1.4	51
	0.4	10.8	11.2	1.3	51
17 bottom	0.7	14.5	15.2	1.2	50
	0.5	14.0	14.5	1.2	51
18 top	28	39.0	67	4.8	97
	28	40.3	68.3	4.8	97
18 bottom	29	37.5	66.5	5.0	98
	28	37.8	65.8	6.0	97
Federal Drinking Water Standard	*	10		2.0	250
Well #18 Control Aug. 1982	2.3	1.6		0.82	27

lagoon 1. The fact that wells 2 and 16 both appear to be contaminated while wells 10 and 17 are relatively "clean" implies a rather clear delineation of the eastern plume boundary.

To gain an understanding of the vertical distribution of the plume, samples were taken from the top and bottom of the aquifer at wells 17 and 18. This was accomplished by isolating the desired section of slotted casing with a specially designed pump housing, capable of sealing off a section of casing above and below the pump with inflatable collars. From this data (Table 1) it can be concluded that vertical stratification is not significant at either of these locations, but rather the constituents are relatively evenly mixed throughout the saturated thickness of the aquifer.

While there are no wells presently available with which to delineate the western boundary, a good approximation can be made with the data at hand. Given the direction of flow, both currently and historically, we see that any westward migration would have to be predominantly by diffusion, due to the lack of any hydraulic gradient to the west. As was pointed out previously, the strata in this region are graded such that permeability is lower in the lateral direction, further inhibiting diffusion to the west. Finally, the reasonably well-defined eastern boundary confirms very little diffusion laterally in this area. It can therefore be assumed that lateral diffusion is not an important factor, thus permitting the approximate definition of the western boundary.

It is known that this plume currently extends beyond Horn Rapids Road and off of Exxon property. Given the velocity of the groundwater and the approximate time and place of release, one can calculate the plume to currently extend about 200-300 feet northeast of the road. Utilizing existing sample analysis data, groundwater level data, and pump test data, it is concluded that the boundaries of the chemically contaminated plume area are as depicted in Figure 8.

PREDICTED MOVEMENT OF THE EXXON PLUME

While the current boundary of the plume is well defined, the future distribution is also of interest. Assuming an original release time of mid 1973, a velocity of about 100 ft/year and a direction of flow to the northeast, the central portion of the plume can be predicted with a good degree of accuracy. In addition, enough is known about the lateral extent of the plume to predict the areas which will be affected.

As can be seen from Figure 9, the plume is expected to flow beneath the DOE property, cross Stevens Drive and eventually enter the Columbia River near the southern end of the 300 area, having little, if any, impact on the river water quality due to dilution. The licensed low-flow for the Columbia River is 36,000 cfs in this area, while the river is about 2,500 ft wide in this

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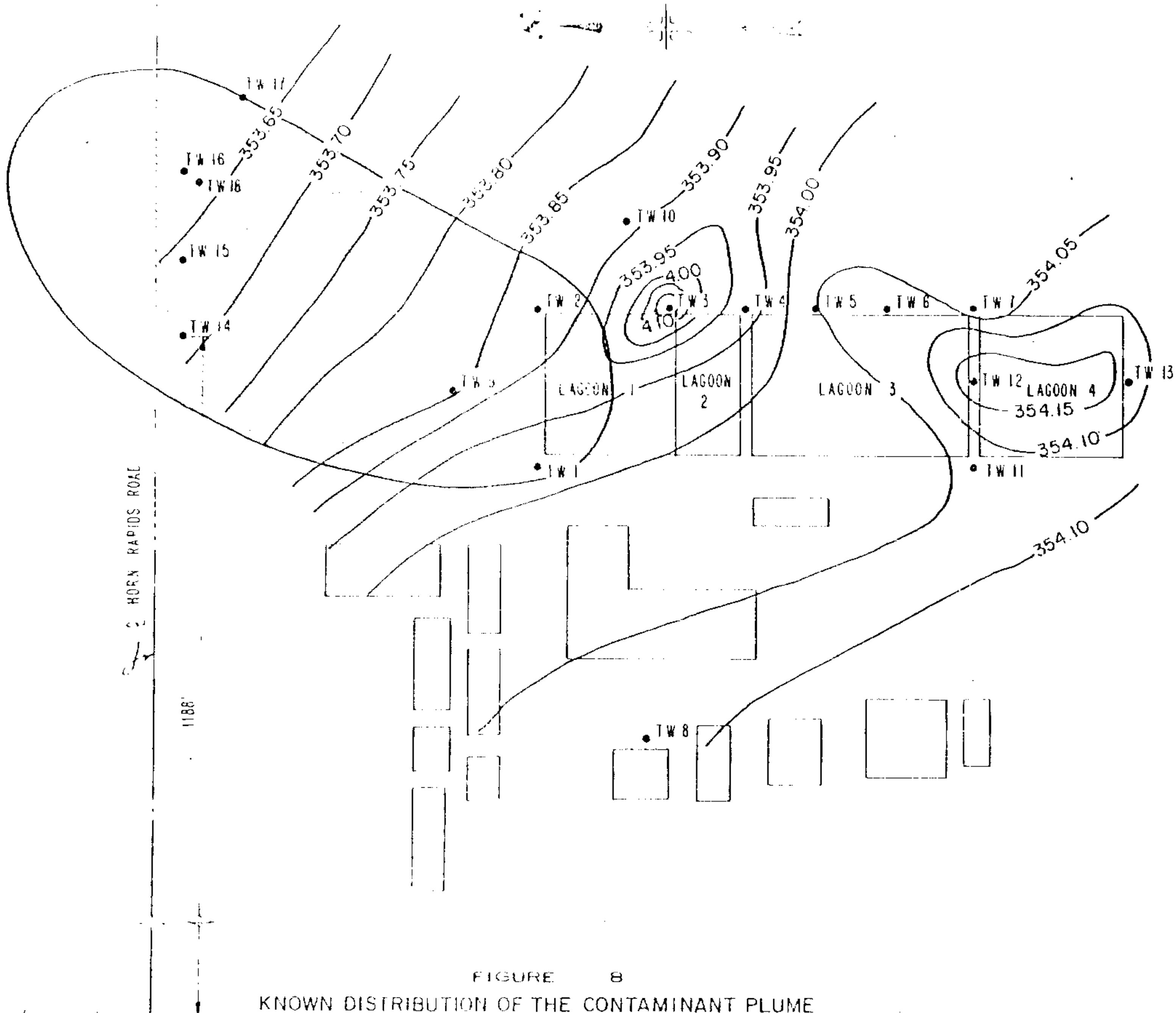

FIGURE 8
KNOWN DISTRIBUTION OF THE CONTAMINANT PLUME
IN THE VICINITY OF THE WASTE LAGOONS
EXXON NUCLEAR COMPANY
MAY, 1982

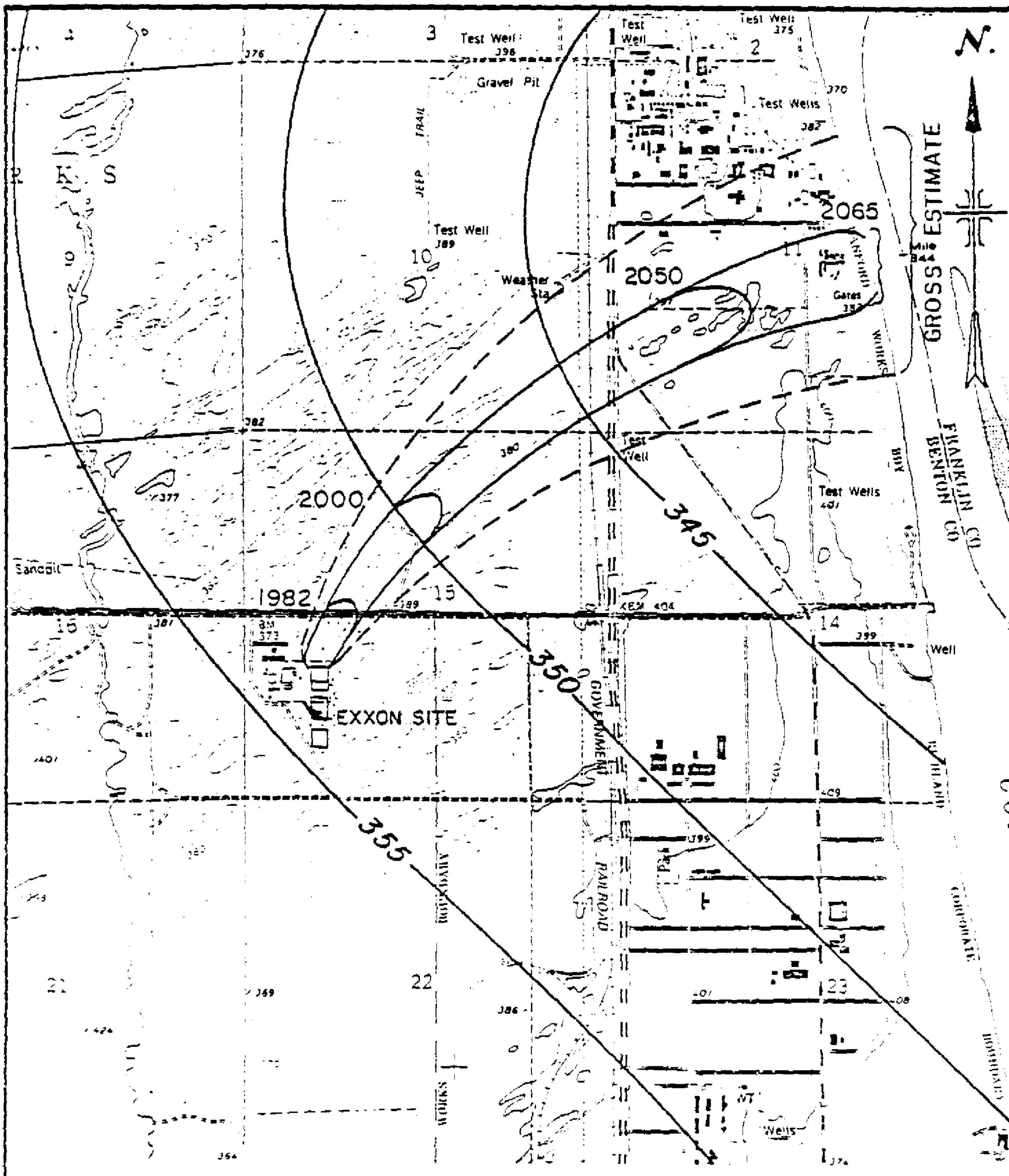

FIGURE 9

PREDICTED DISTRIBUTION OF THE CONTAMINANT PLUME

EXXON NUCLEAR COMPANY

region. The discharge of the river, in cfs, can be envisioned as the velocity of the water (ft/sec) multiplied by the cross sectional area of the river (ft^2), resulting in discharge (ft^3/sec). Assuming on area of 3.75×10^6 ft^2 to be affected by the plume (3000 ft of shore * half the width of the river, or 1250 ft), and a velocity of 100 ft/year, we get an input of about 12 cfs to the river from the expected plume.

Dates have been included to provide some sort of time reference for this sequence of events, with arrival at the Columbia calculated for approximately 2065. The expected lateral extent of the plume, assuming consistent soil characteristics along its path, is indicated by the solid boundary lines in Figure 9. The broken lines indicate the boundaries should lateral diffusion be twice that which is expected.

SIGNIFICANCE OF THE EXXON PLUME TO THE SURROUNDING AREA

Groundwater is currently used in this region of the state for three main purposes: Agricultural irrigation, industrial processes, or human consumption. Three of the four main constituents of the plume, ammonia nitrogen, nitrate nitrogen, and sulfate, are all major components of most fertilizer compositions. The fluoride in the plume would not be expected to bioaccumulate within the plant material or otherwise affect the crop. It would appear that the use of this aquifer for irrigation purposes could potentially prove beneficial. Such land use is not anticipated in this specific location however, due to the specialized ownership and use characteristics of the lands affected by the plume. As was stated previously, the area (including the 300 area), is dedicated to nuclear energy research and development purposes, thereby ruling out agriculture for most intents and purposes.

The second category, industrial processes, would most likely not be affected by the level of constituents within the plume. This assumption would depend upon the type of process involved, however. If the water was needed solely for cooling purposes, there would probably be little problem involved. If, however, a clean source of water were required for actual use in a manufacturing or chemical processing industry, problems could possibly develop. Again, this is dependent upon the process involved.

The last category, human consumption, is where the only real degree of concern exists. As can be seen from Table 1, the levels of chemicals within the plume greatly exceed the Federal limits for drinking water. As a result of this contamination, the groundwater within this aquifer would be unfit for human consumption in the vicinity of the plume. Should groundwater be required for drinking purposes within the region of the plume, the wells would have to be drilled to the second, confined aquifer below the contaminated, unconfined aquifer. This would require drilling about an additional 50-100 feet, depending upon location. It is highly unlikely that this aquifer would be used for human consumption purposes in the future. The water quality in the 300 area is well documented as to being highly contaminated due to the long history of radioactive waste disposal in this area.[1] In addition, this region is currently served by city water lines from the City of Richland, making groundwater use impractical for drinking purposes.

CONCLUSIONS

1. Groundwater hydrology for the region is currently well defined.

2. Groundwater flows to the north and northeast from the Exxon site.

3. Groundwater velocities range from 50-170 ft/year, with an average of about 100 ft/year.

4. Evidence exists for two occurrences of leaks, one in 1973 and one in 1977.

5. Contaminant plume is currently 500-600 feet wide, 1000-1100 feet long and 40-50 feet wide.

6. The plume should reach the Columbia River by the year 2065 in an area south of the 300 area.

7. The use of groundwater in the region affected by the plume is not anticipated during this time period. If such use is required however, the second aquifer should remain unaffected.

8. The wastewater plume should have little, if any, effect upon water quality within the Columbia River.

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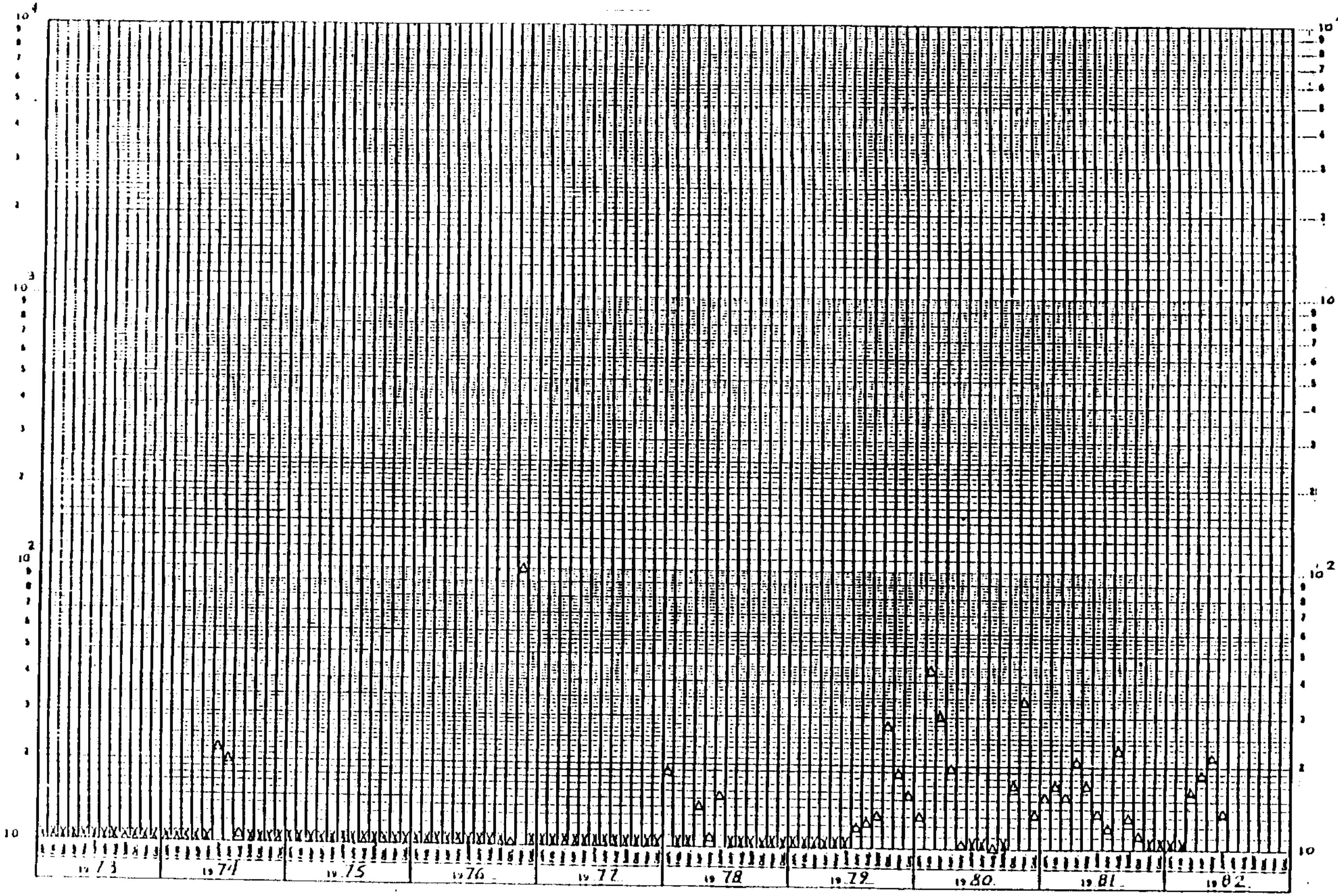
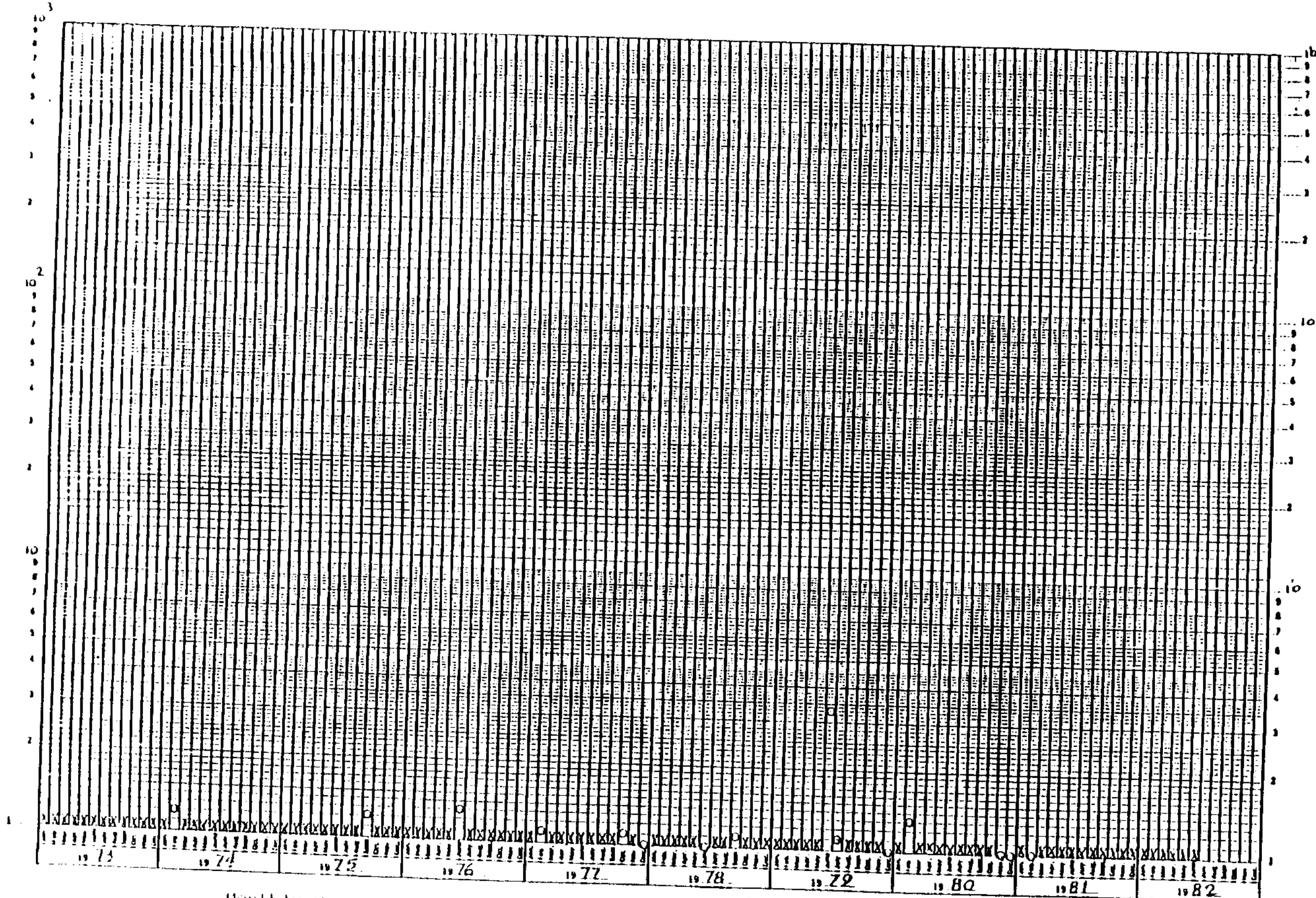
APPENDIX IA

Water Quality Data For Wells 4,5,6



Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 4

Note: x = less than 10 ppm.



Monthly Concentration of Fluoride in Test Well No. 4

Note: x = less than 1 ppm.

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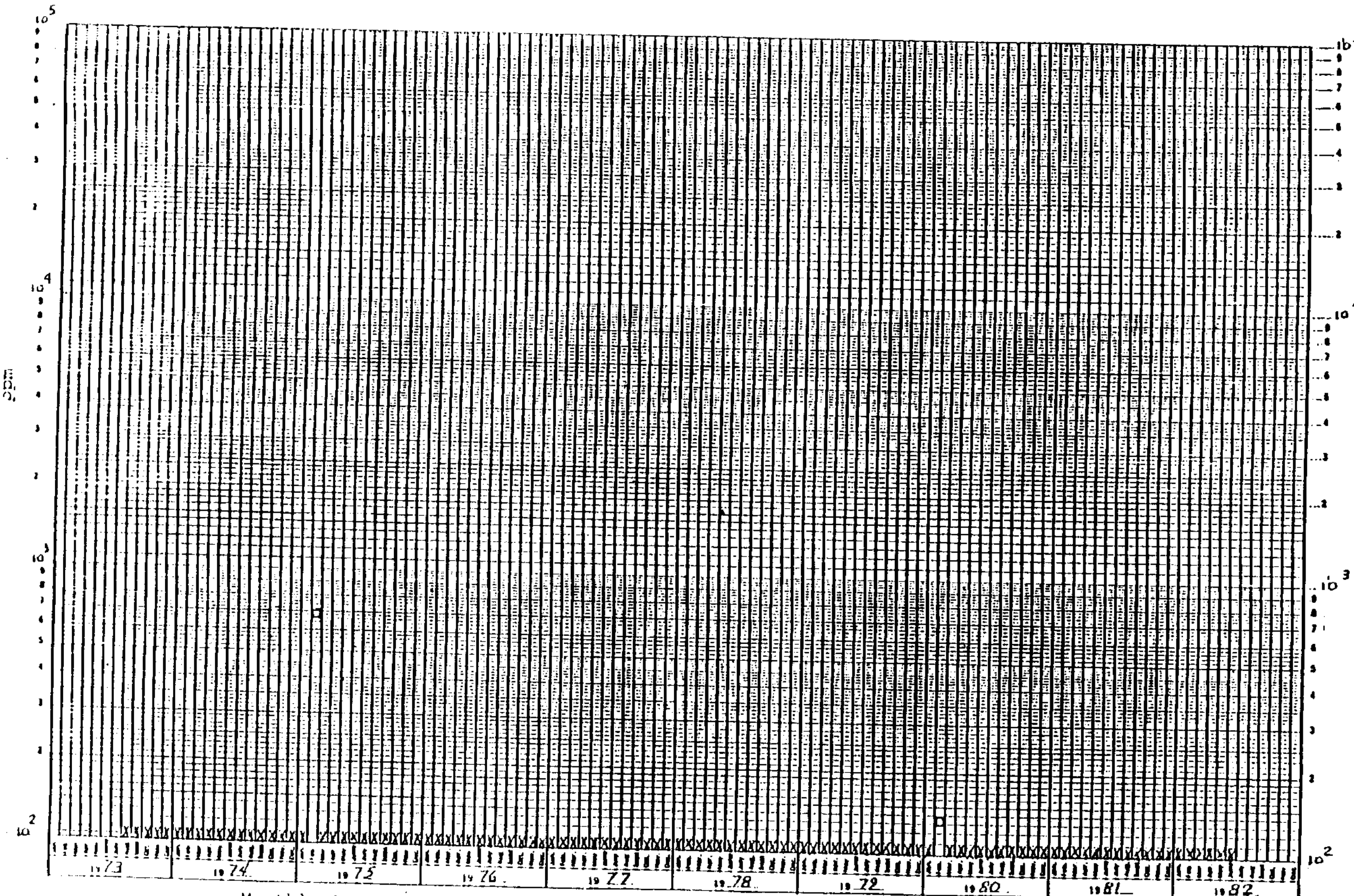

Monthly Concentration of Sulfate in Test Well No. 4

Note: x = less than 100 ppm.

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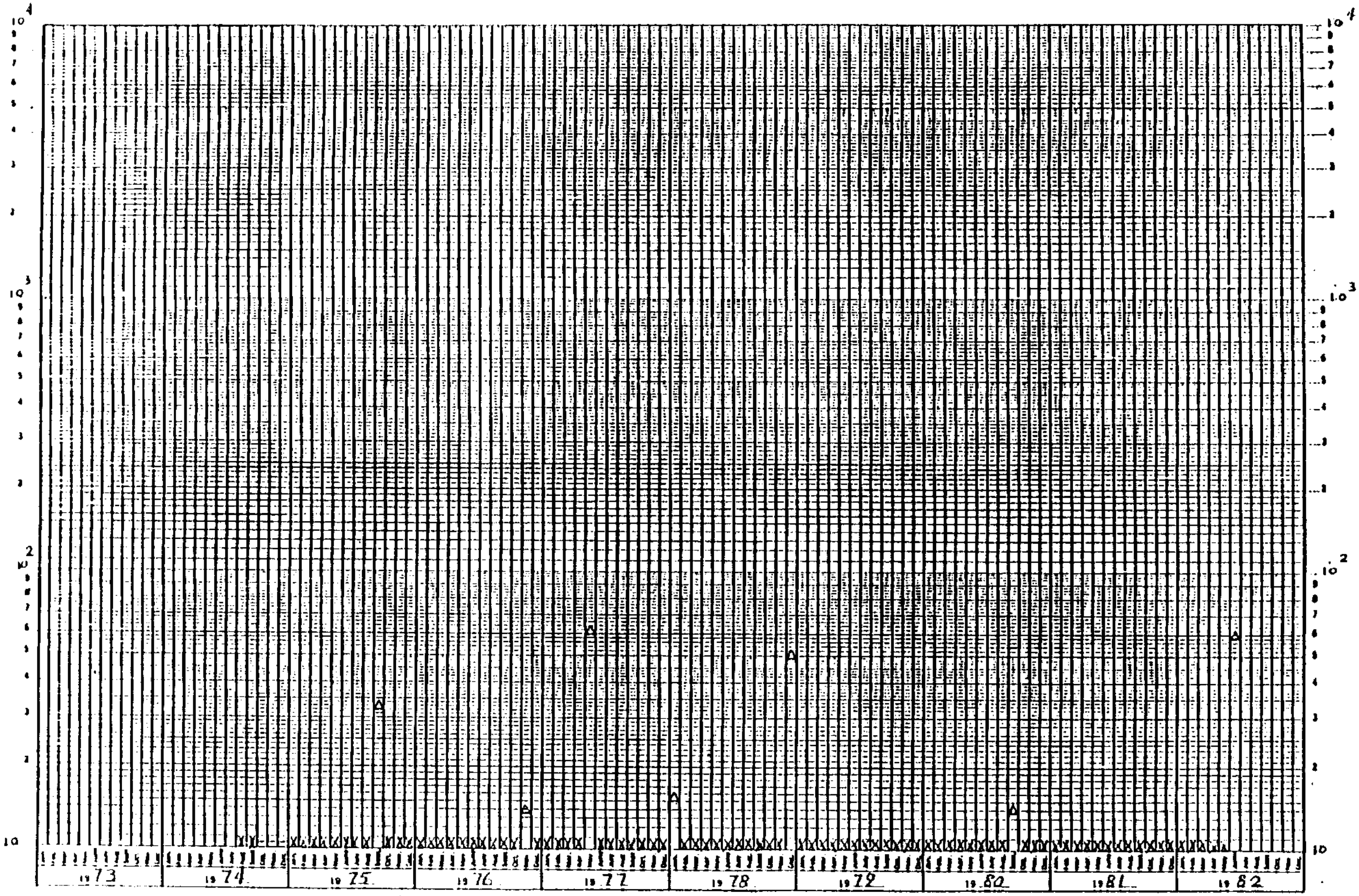
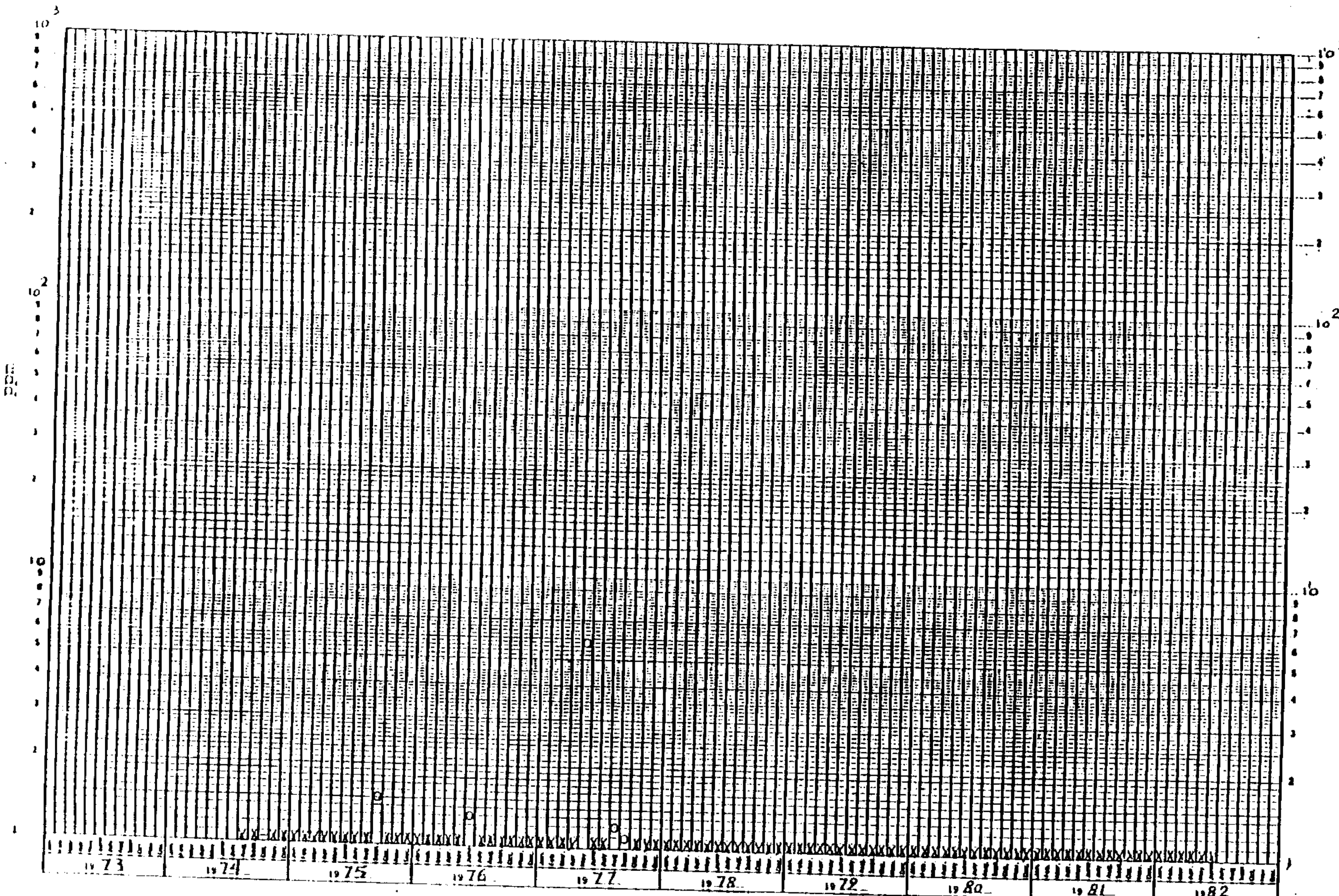


Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 5

Note: x = less than 10 ppm.



Monthly Concentration of Fluoride in Test Well No. 5

Note: x = less than 1 ppm.

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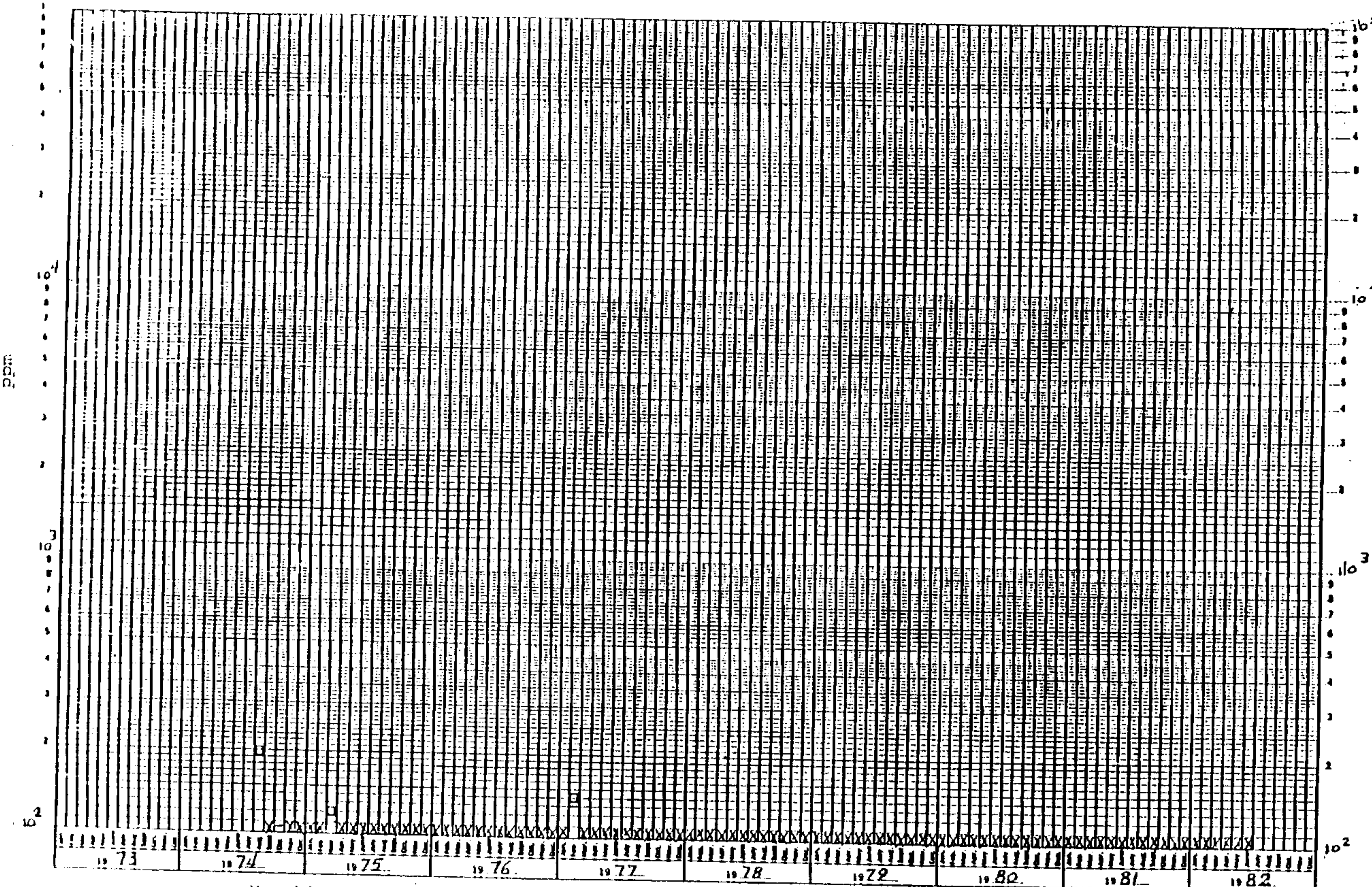
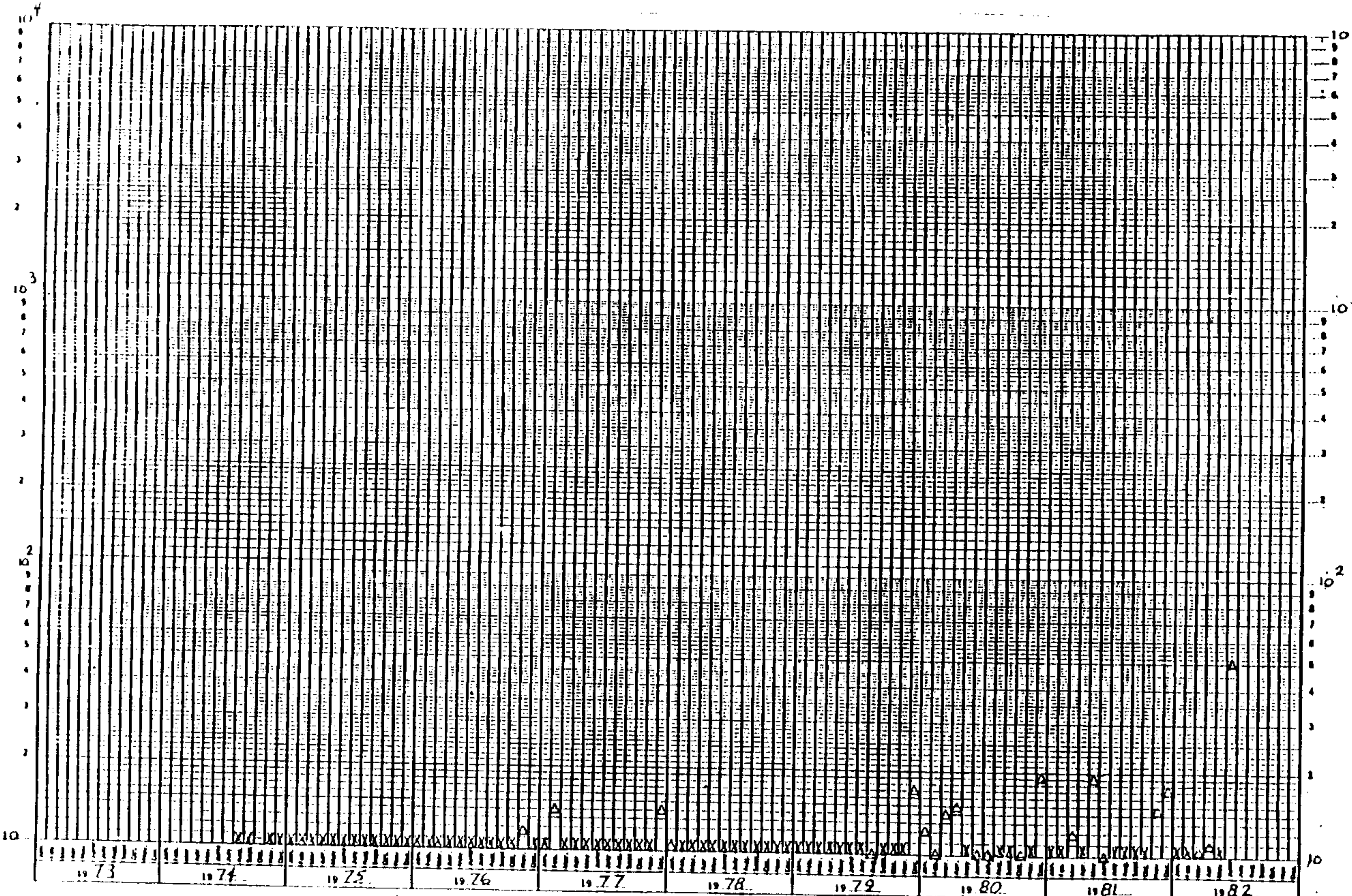


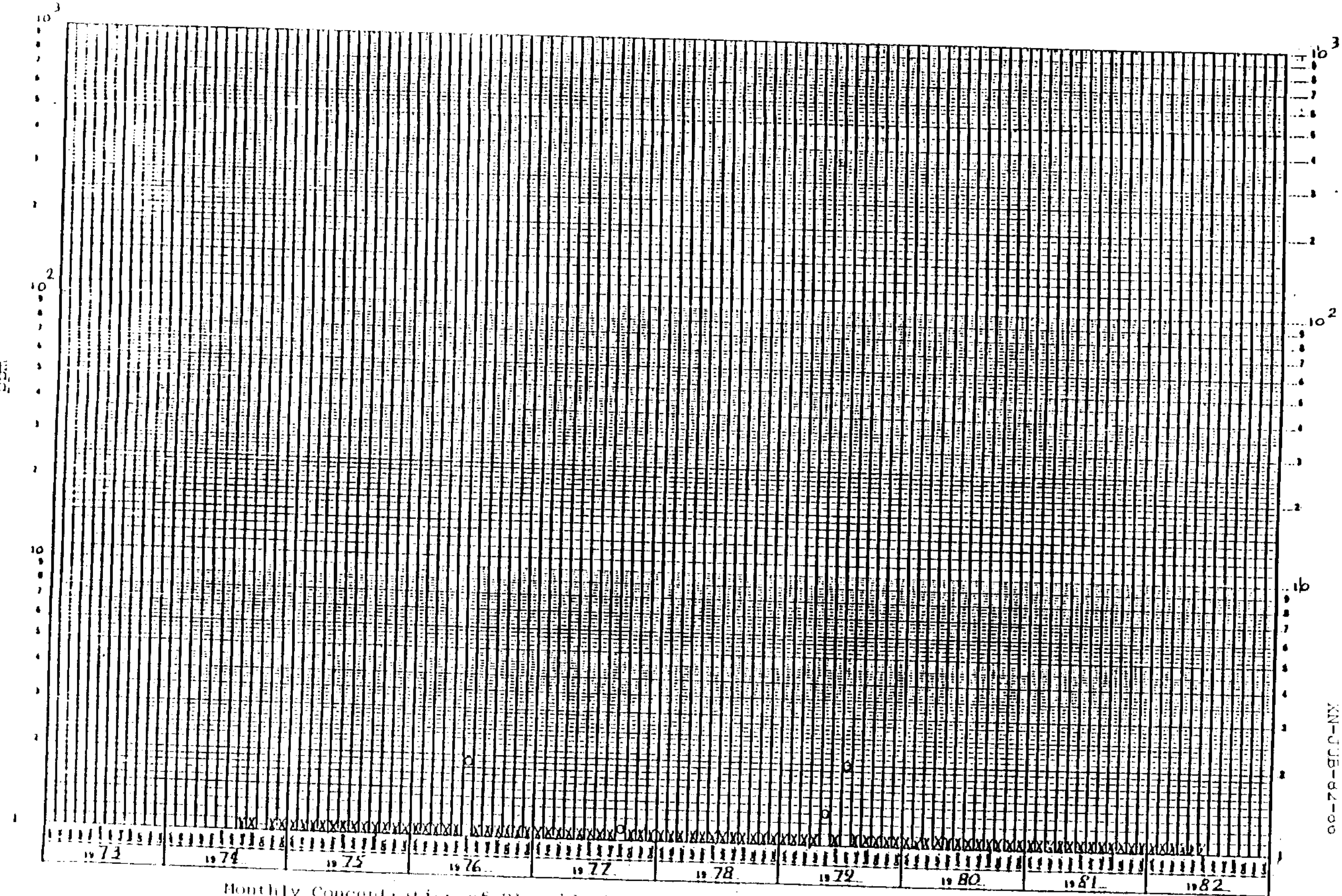
Monthly Concentration of Sulfate in Test Well No. 5

Note: x = less than 100 ppm.



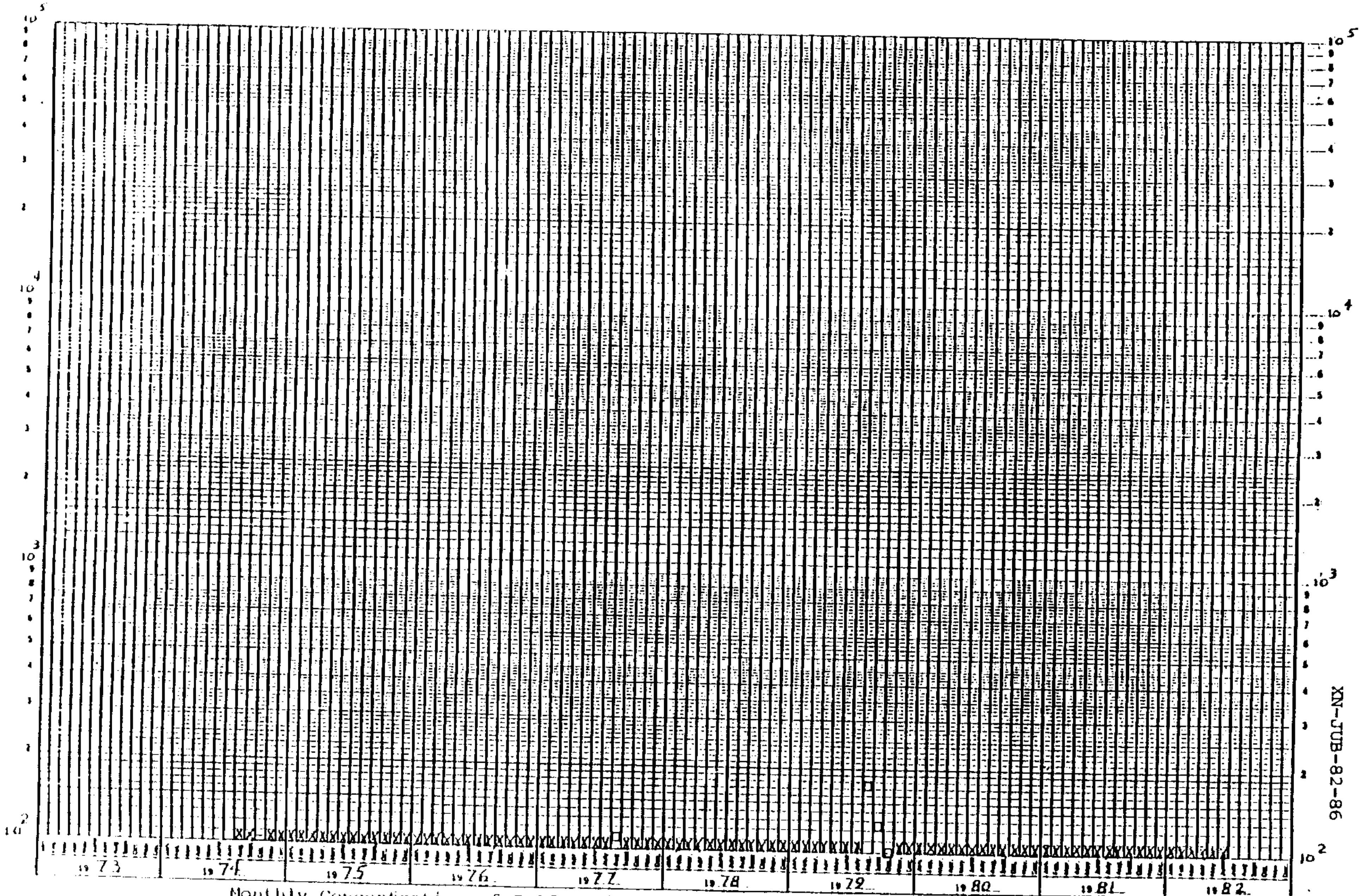
Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 6

Note: x = less than 10 ppm.



Monthly Concentration of Fluoride in Test Well No. 6

Note: x - less than 1 ppm.



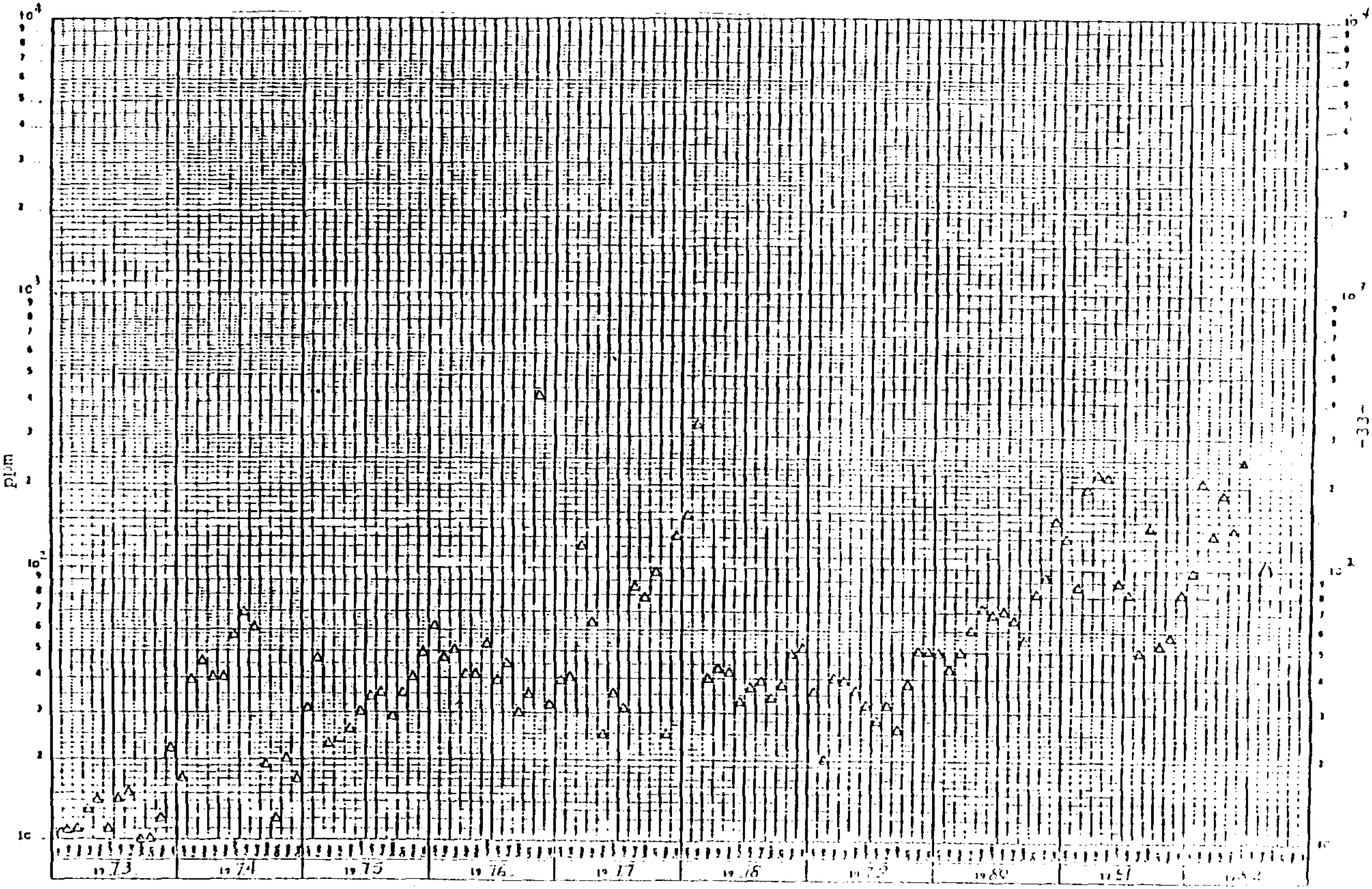
Monthly Concentration of Sulfate in Test Well No. 6

Note: x = less than 100 ppm.

APPENDIX IB

Water Quality Data For Wells 1,2,3,8,9,10

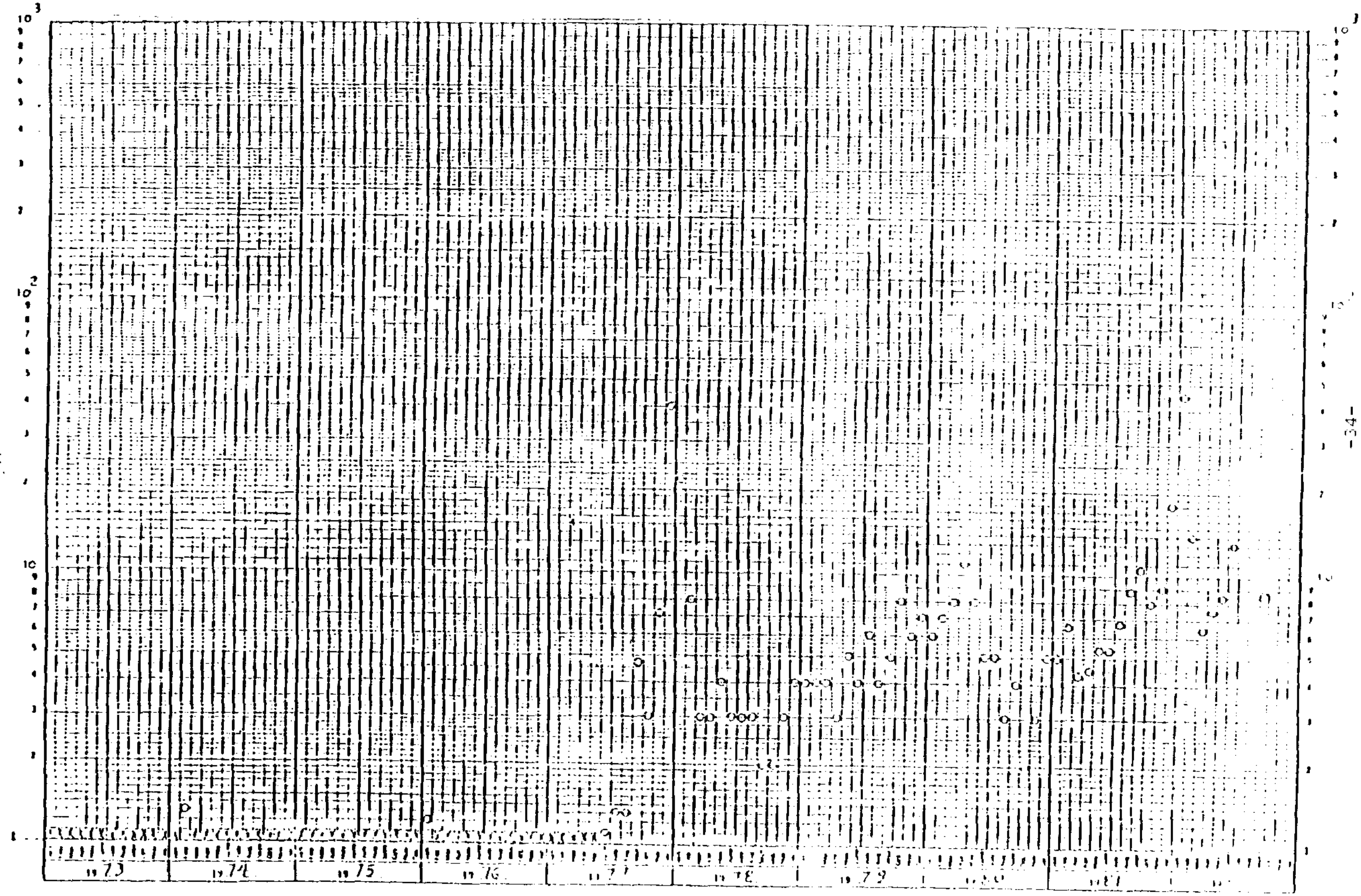
XN-JUB-82-86



Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 1

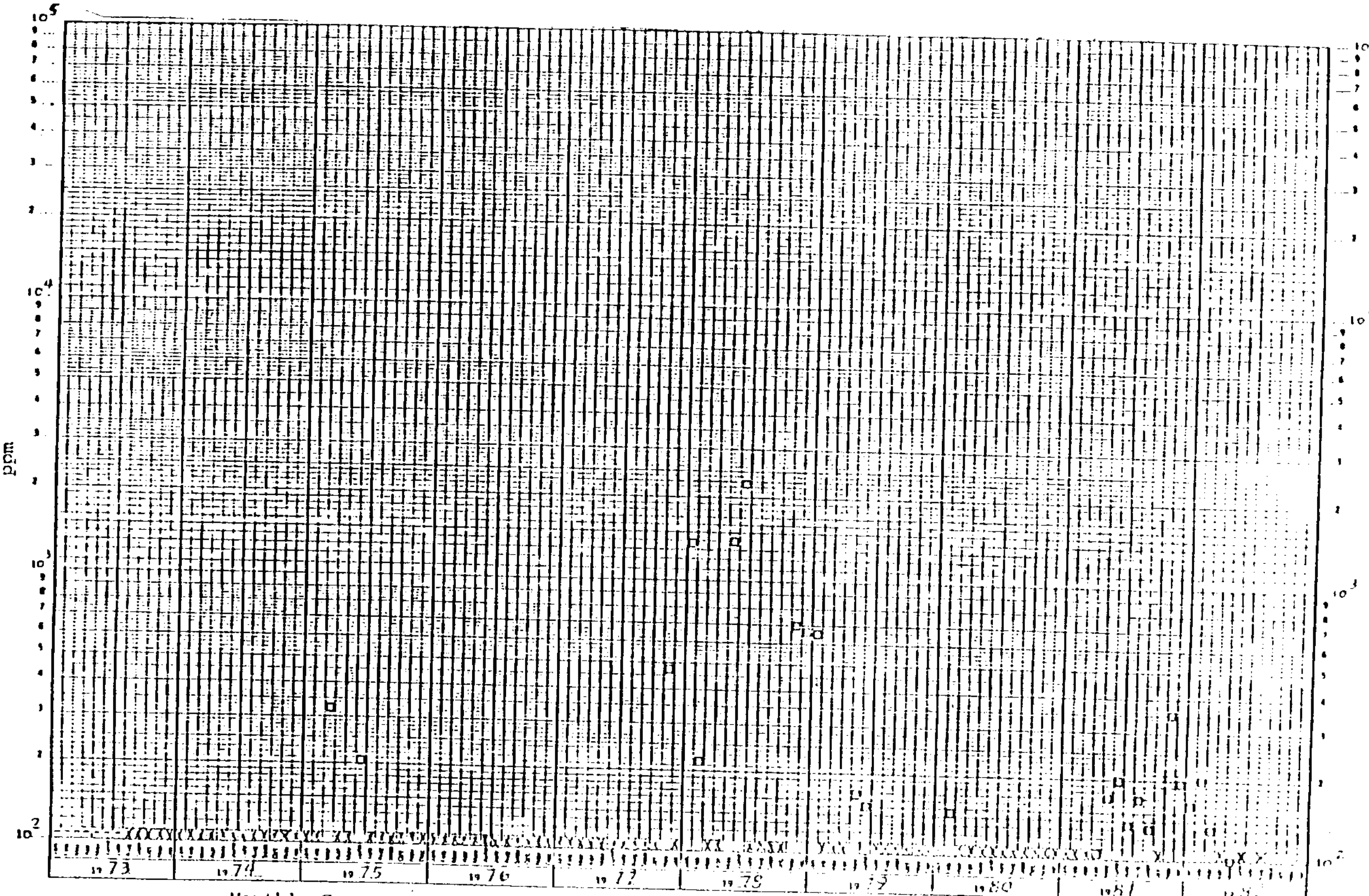
Note: x = less than 10 ppm.

XN-JUB-82-86



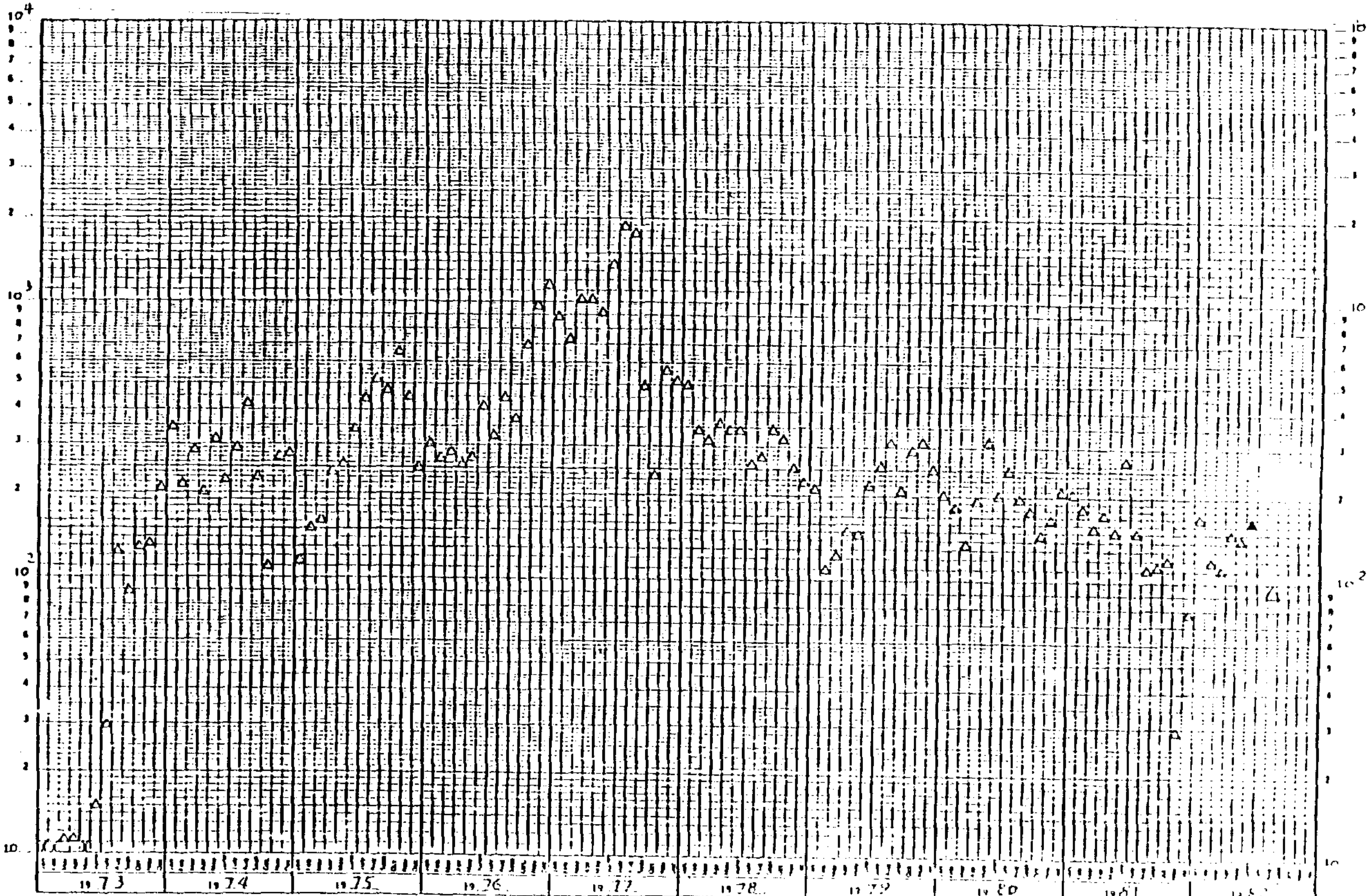
Monthly Concentration of Fluoride in Test Well No. 1

Note: x = less than 1 ppm.



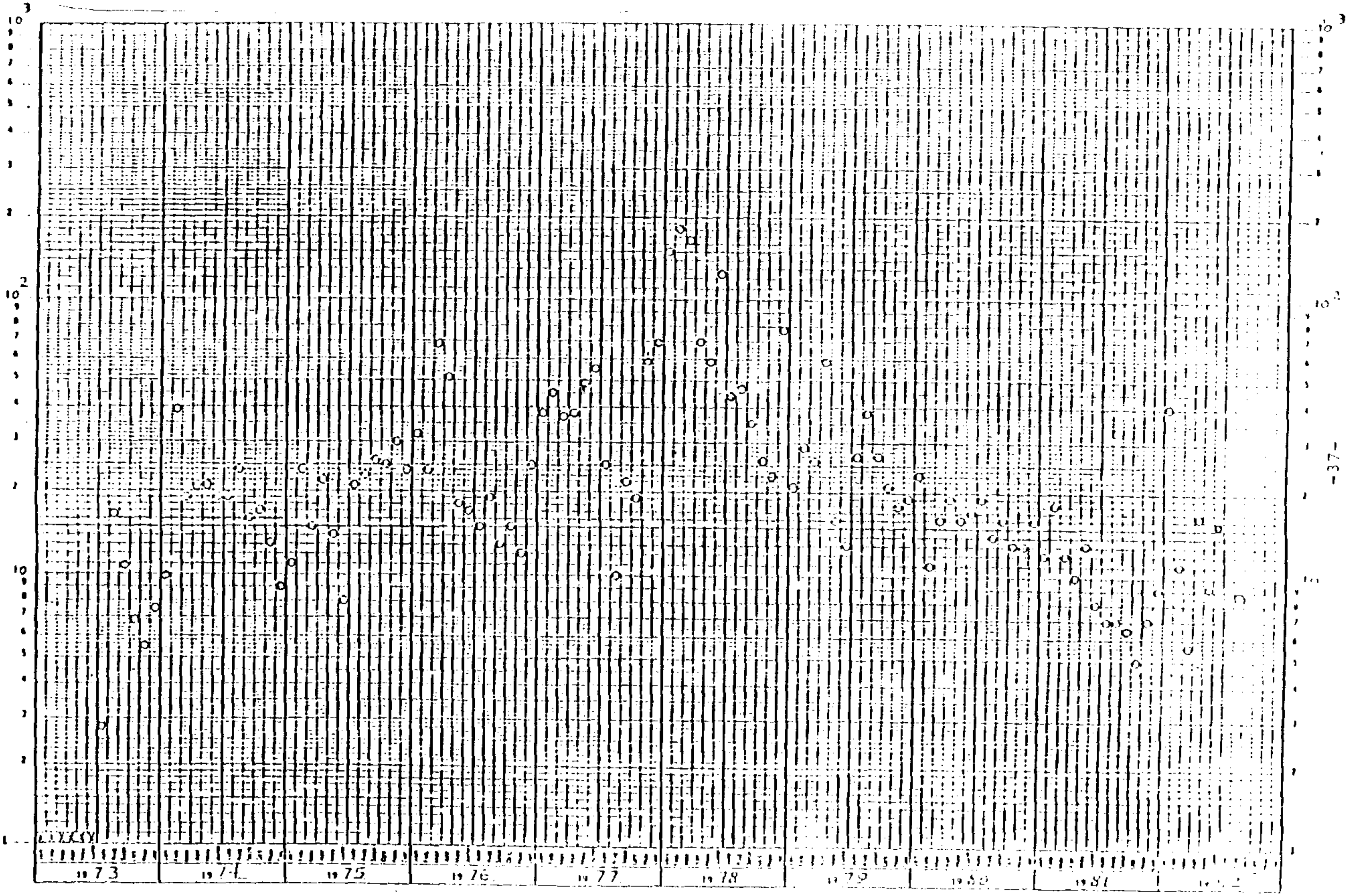
Monthly Concentration of Sulfate in Test Well No. 1

Note: x = less than 100 ppm.



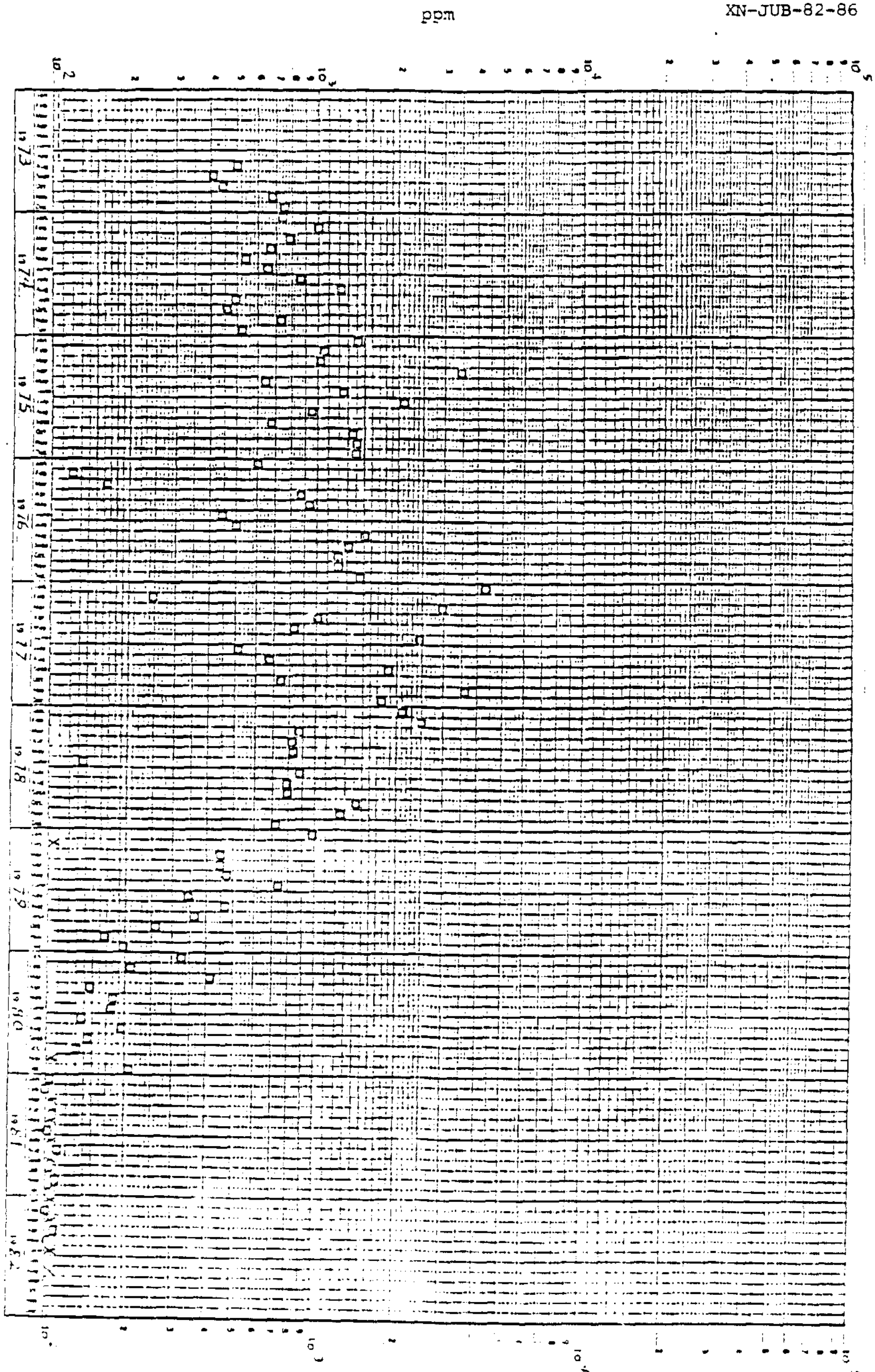
Monthly Concentration of Nitrogen (as $NO_3 + NH_4$) in Test Well No. 2.

Note: x = less than 10 ppm.



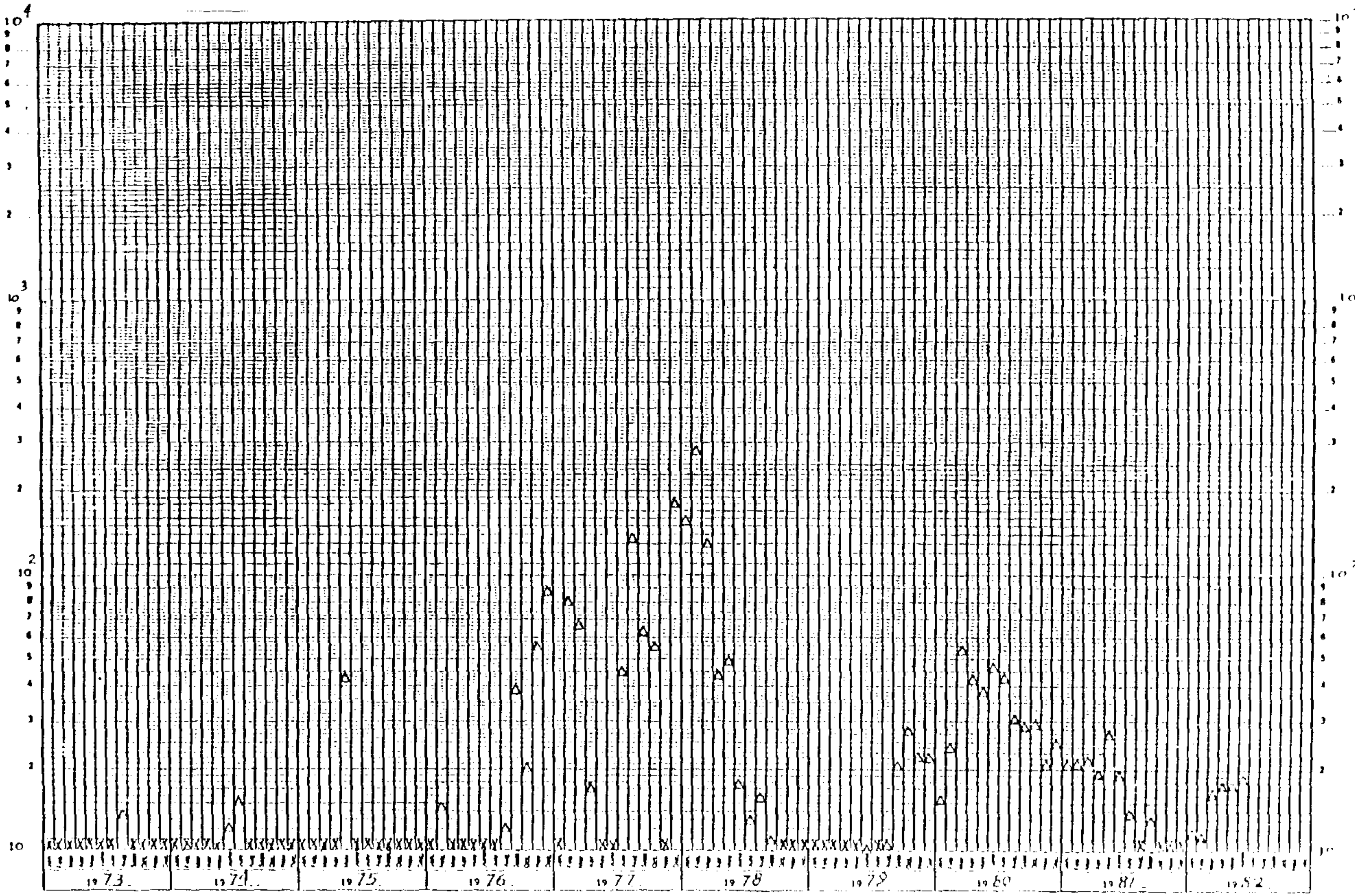
Monthly Concentration of Fluoride in Test Well No. 2

Note: x = less than 1 ppm.



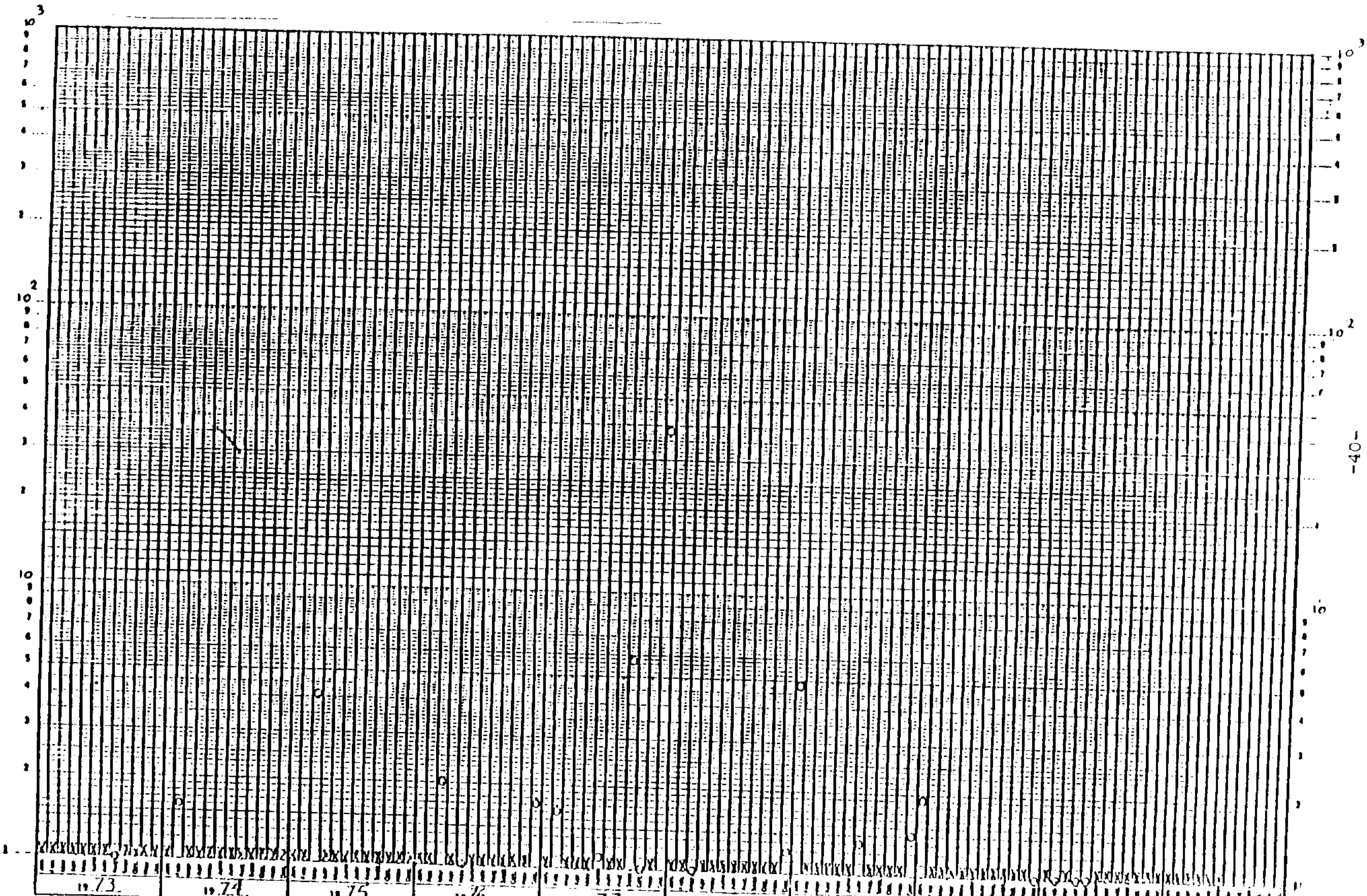
Monthly Concentration of Sulfate in Test Well No. 2

Note: x = less than 100 ppm.



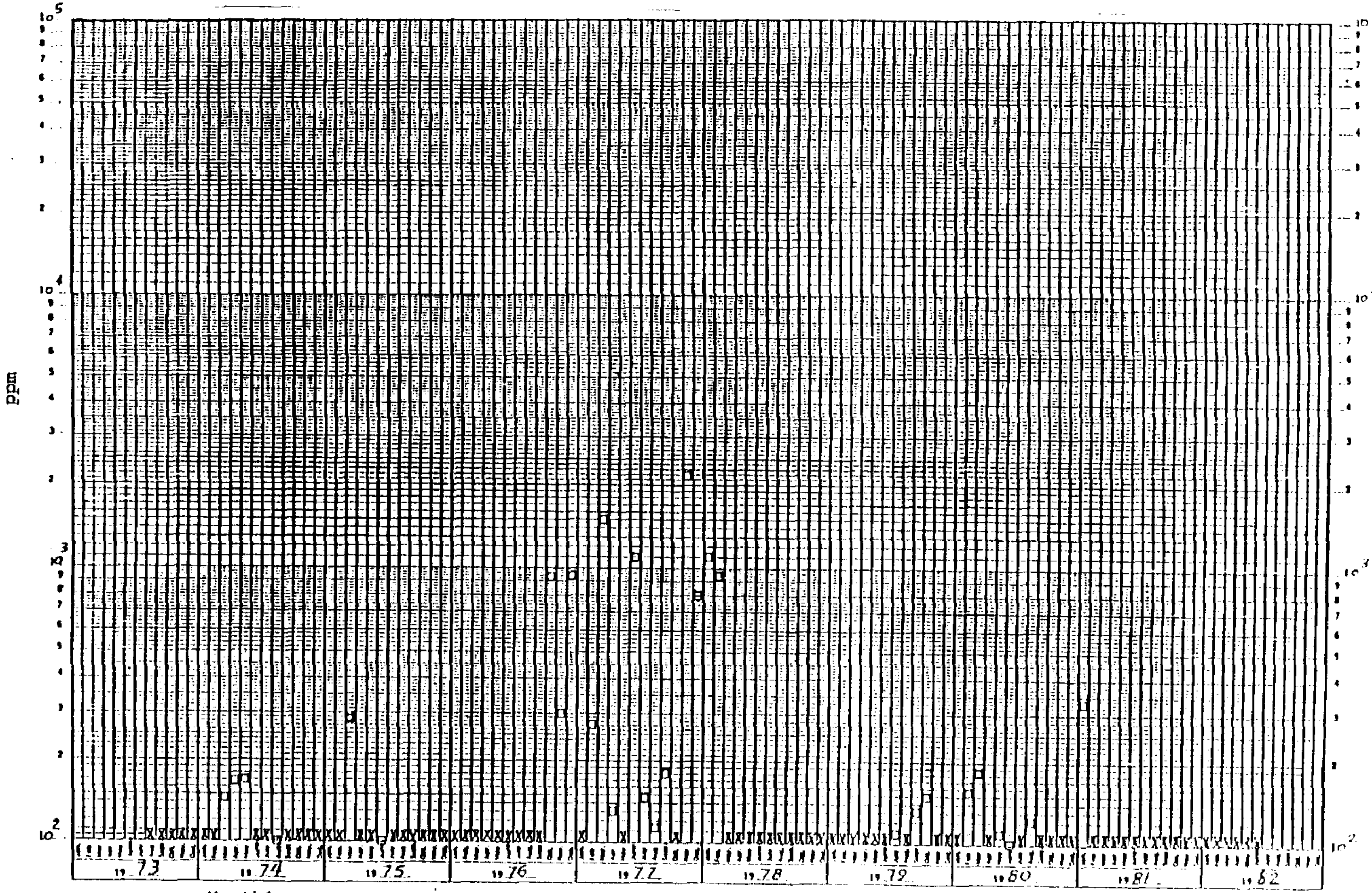
Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 3

Note: x = less than 10 ppm.



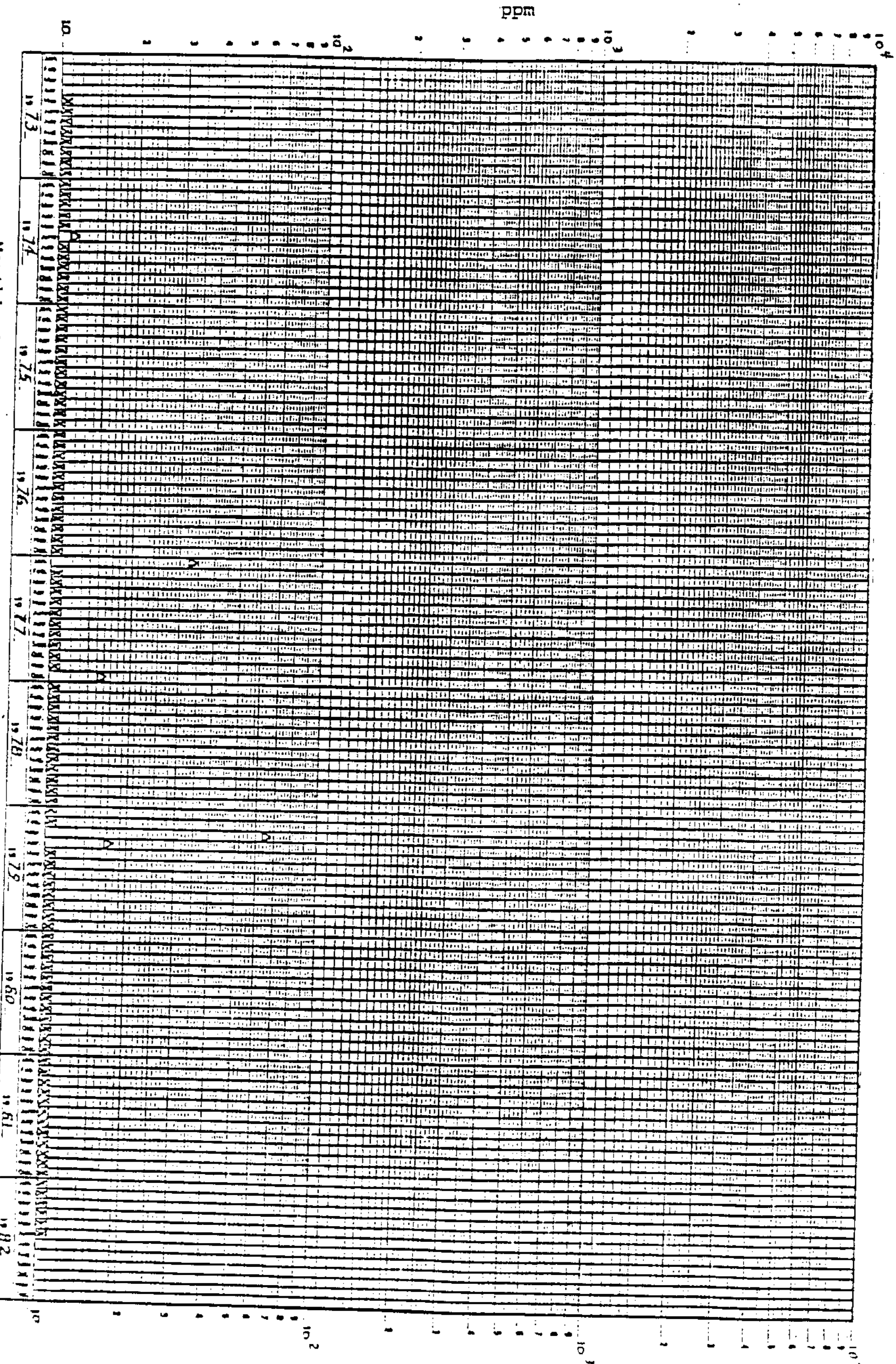
Monthly Concentration of Fluoride in Test Well No. 3

Note: x = less than 1 ppm.



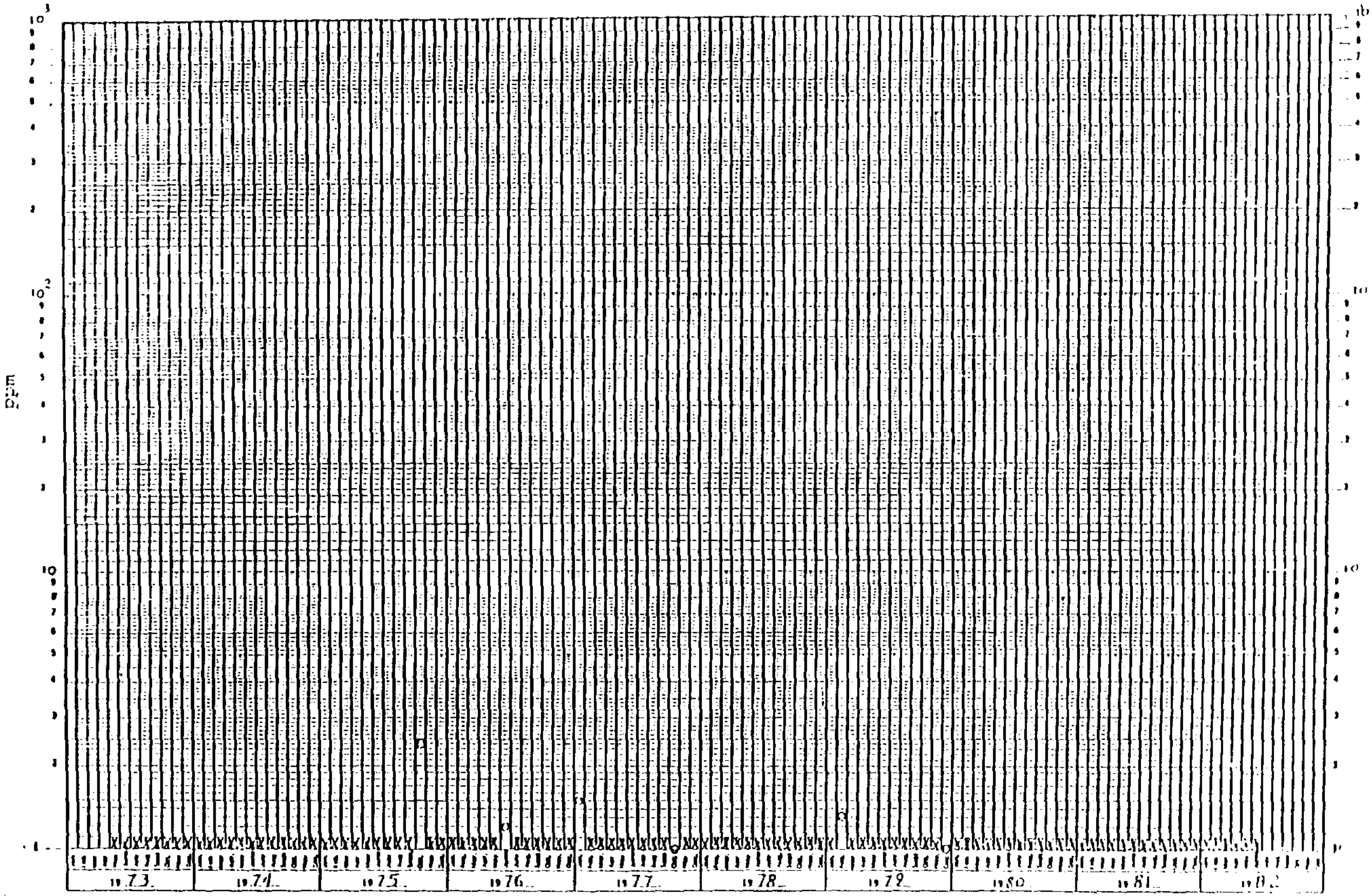
Monthly Concentration of Sulfate in Test Well No. 3

Note: x = less than 100 ppm.



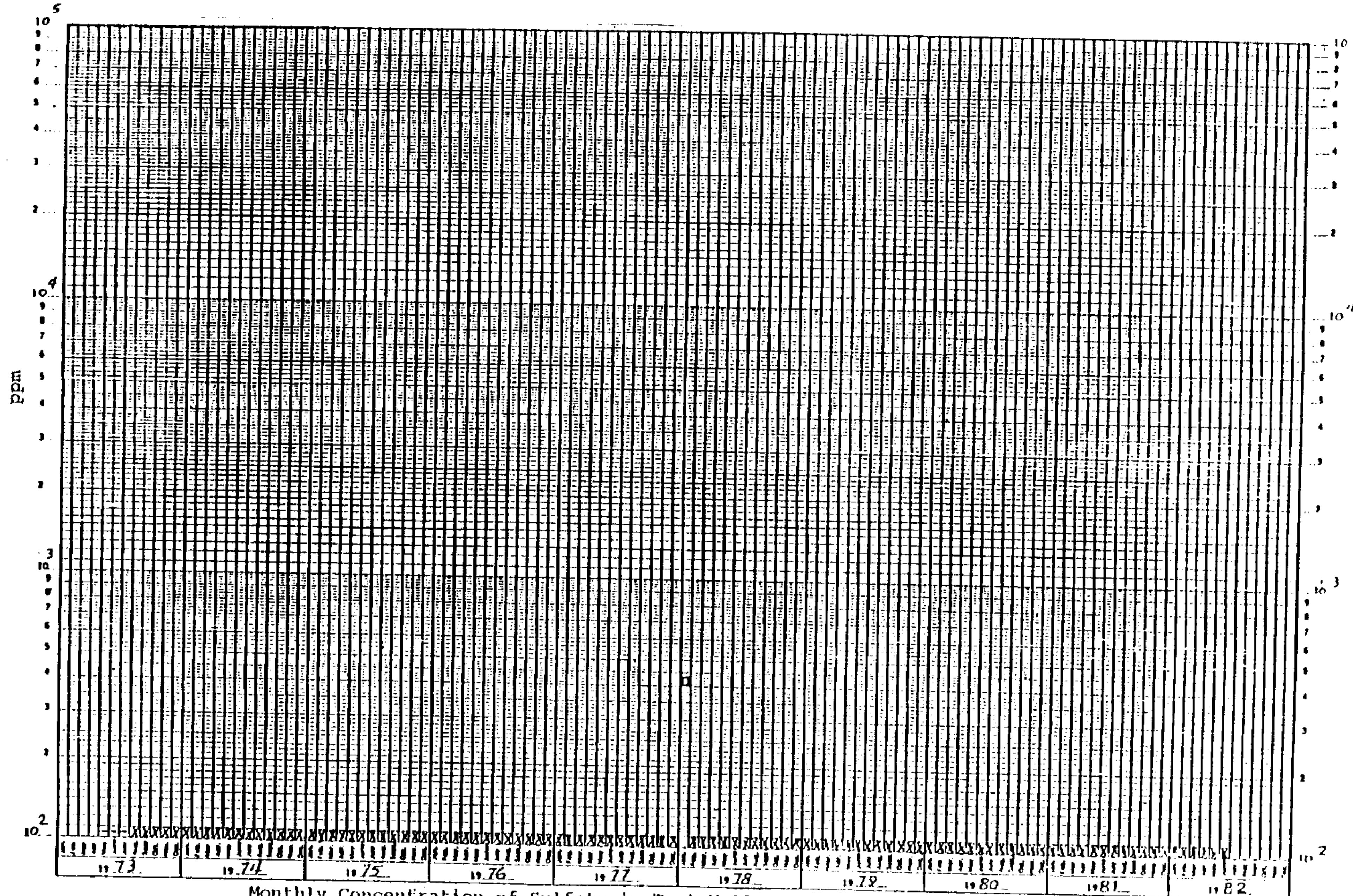
Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 8

Note: x = less than 10 ppm.



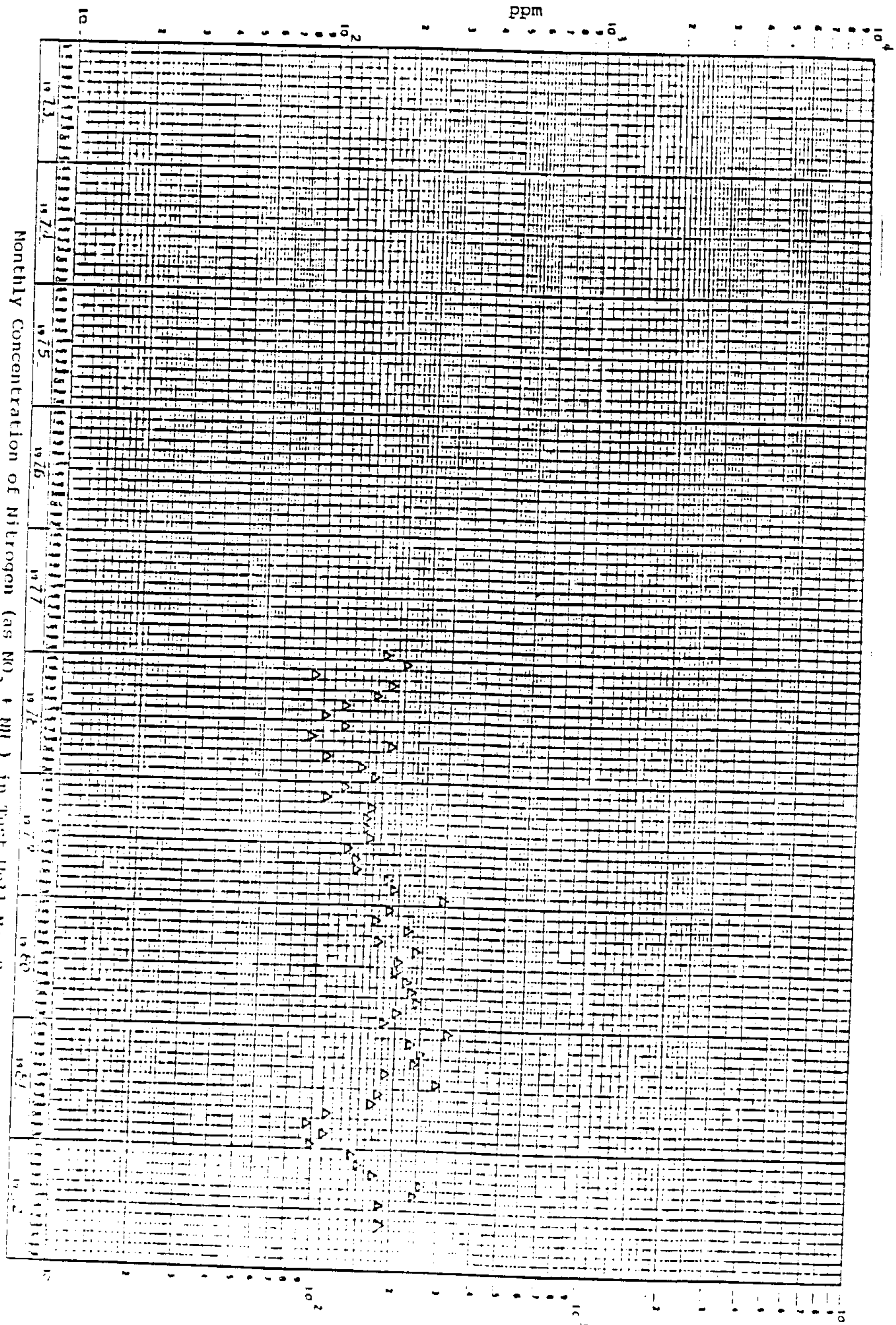
Monthly Concentration of Fluoride in Test Well No. 8

Note: x = less than 1 ppm.



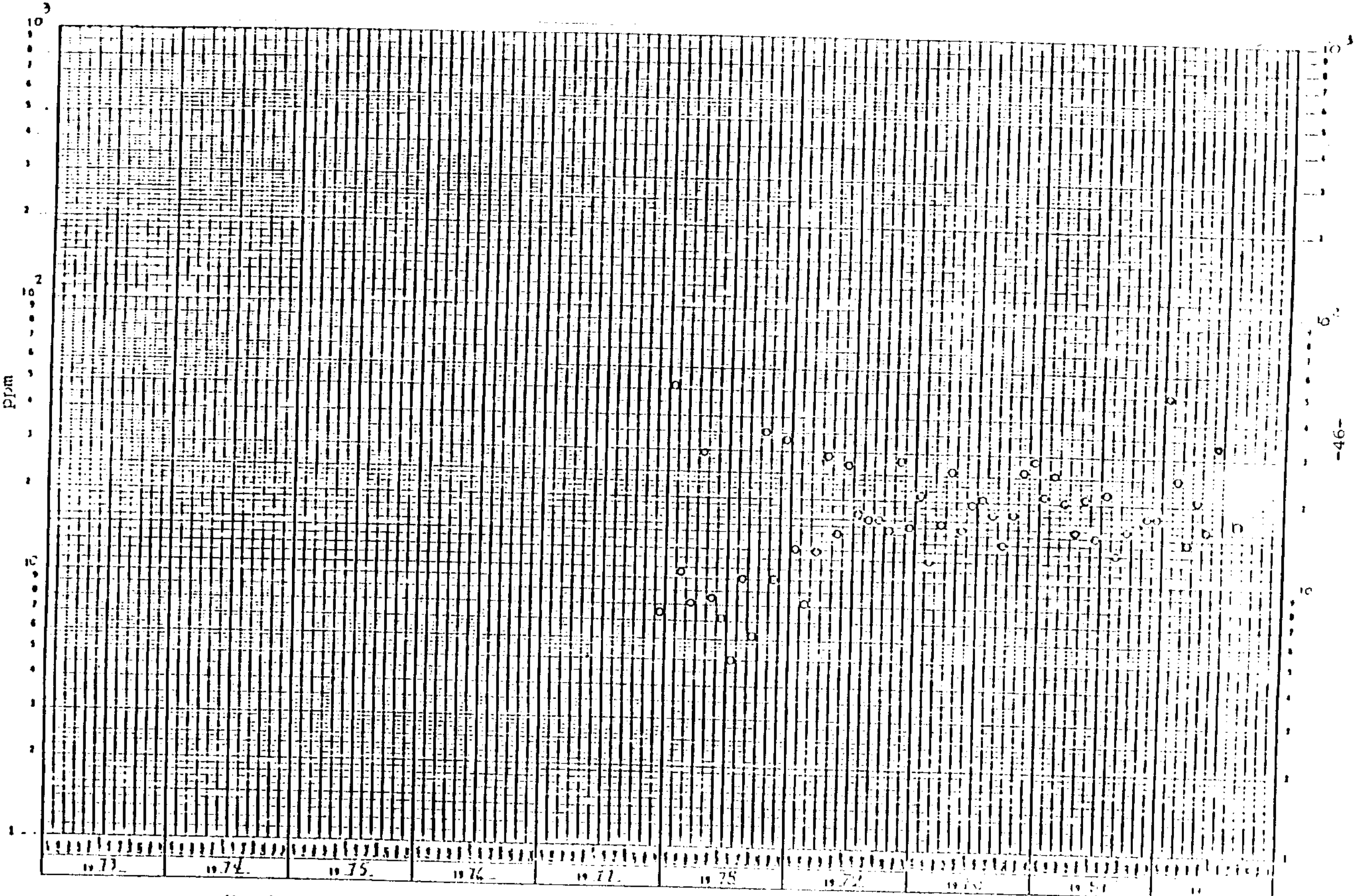
Monthly Concentration of Sulfate in Test Well No. 8

Note: x = less than 100 ppm.



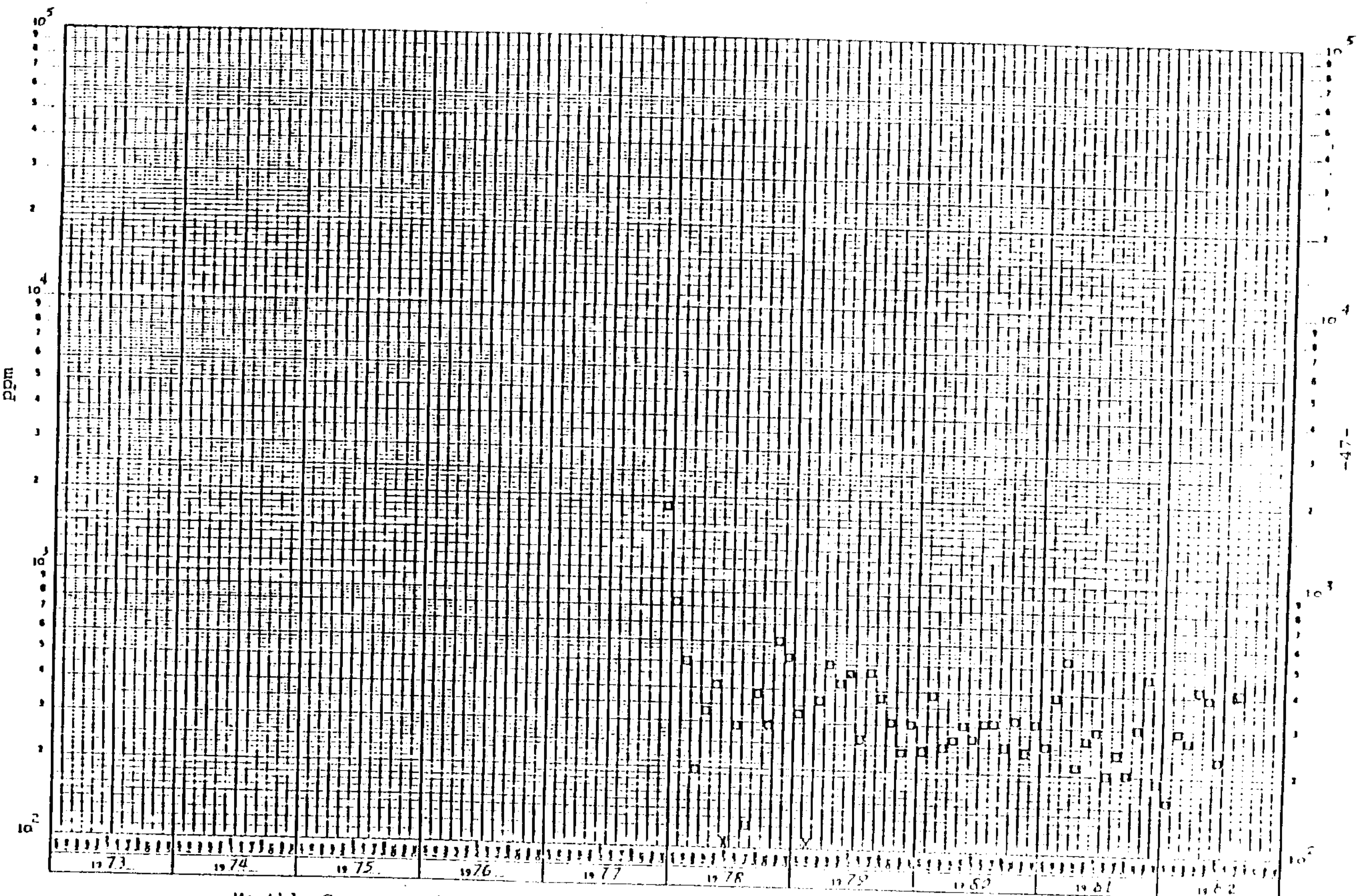
Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 9

Note: x = less than 10 ppm.



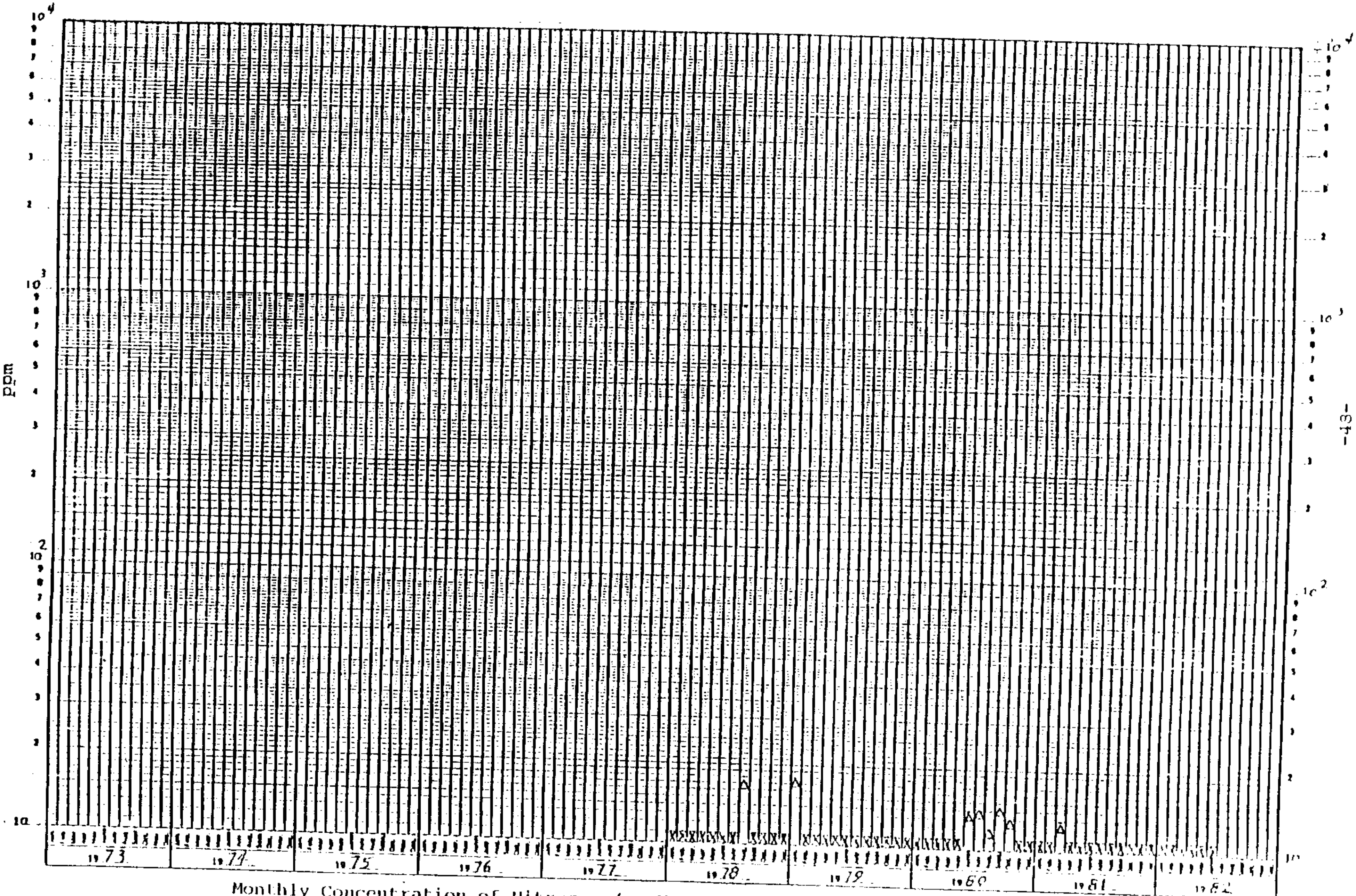
Monthly Concentration of Fluoride in Test Well No. 9

Note: x = less than 1 ppm.



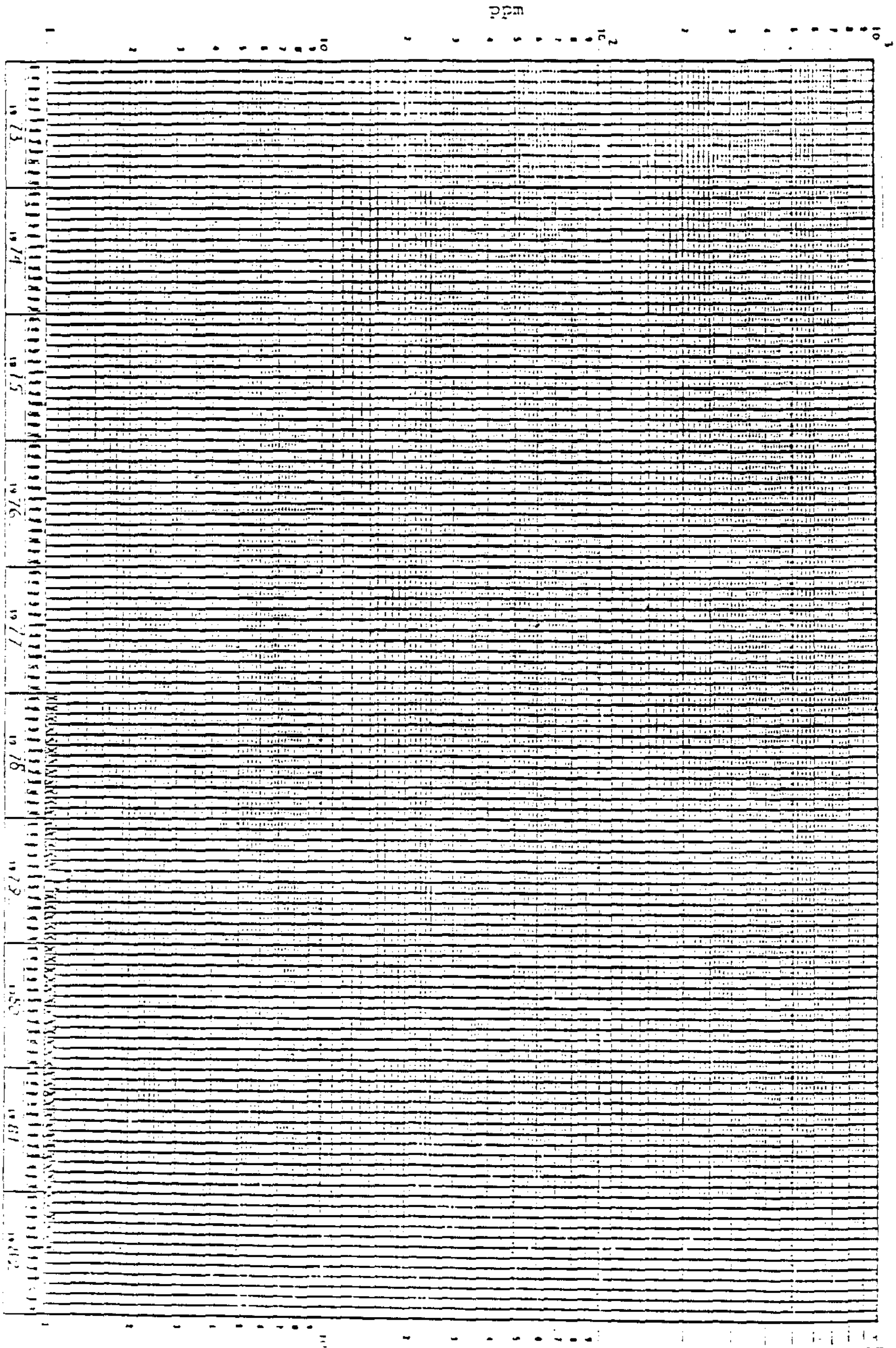
Monthly Concentration of Sulfate in Test Well No. 9

Note: x = less than 100 ppm.



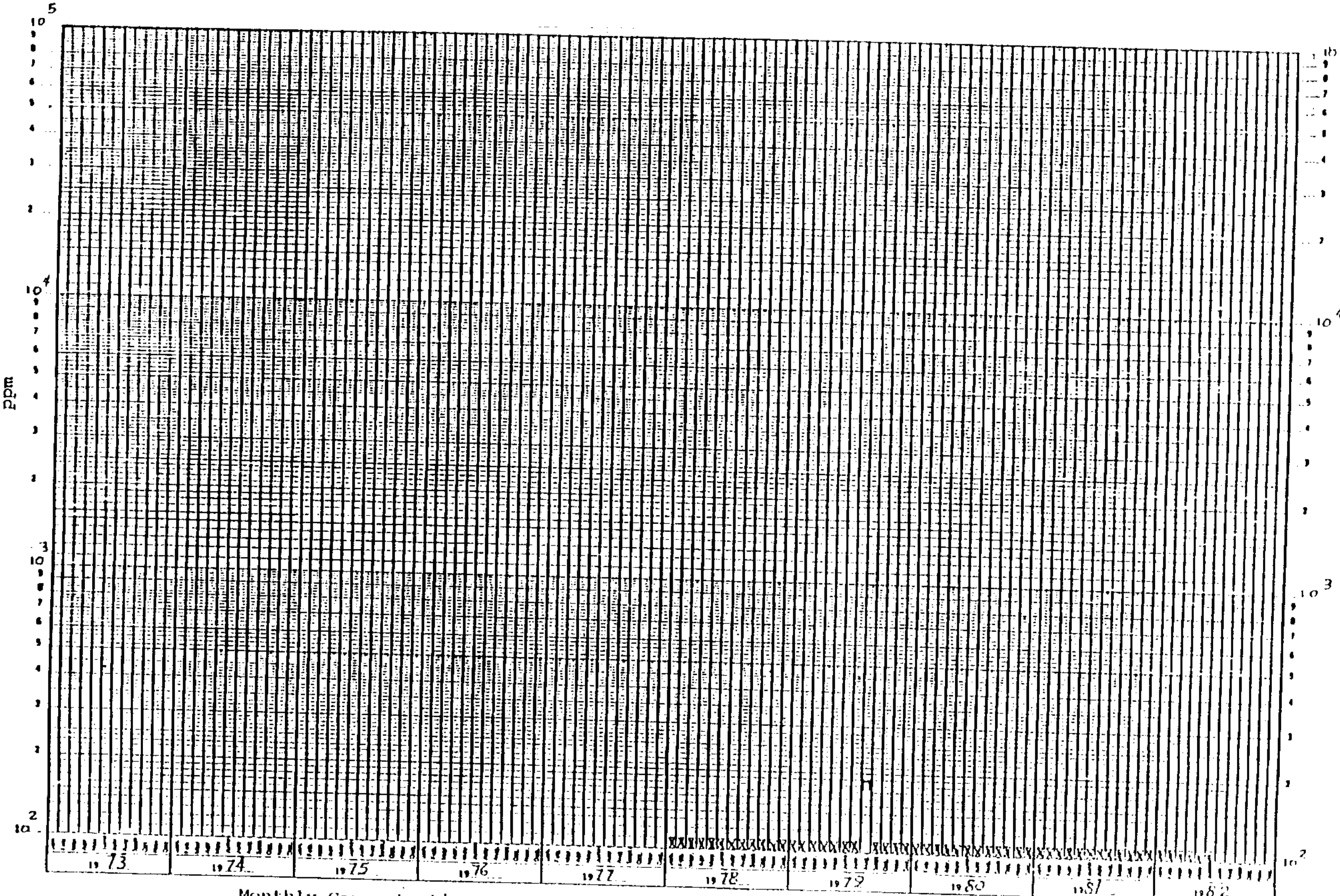
Monthly Concentration of Nitrogen (as NO_3 + NH_4) in Test Well No. 10

Note: x = less than 10 ppm.



Monthly Concentration of Fluoride in Test Well No. 10

Note: x - less than 1 ppm.



Monthly Concentration of Sulfate in Test Well No. 10

Note: x - less than 100 ppm.

APPENDIX II

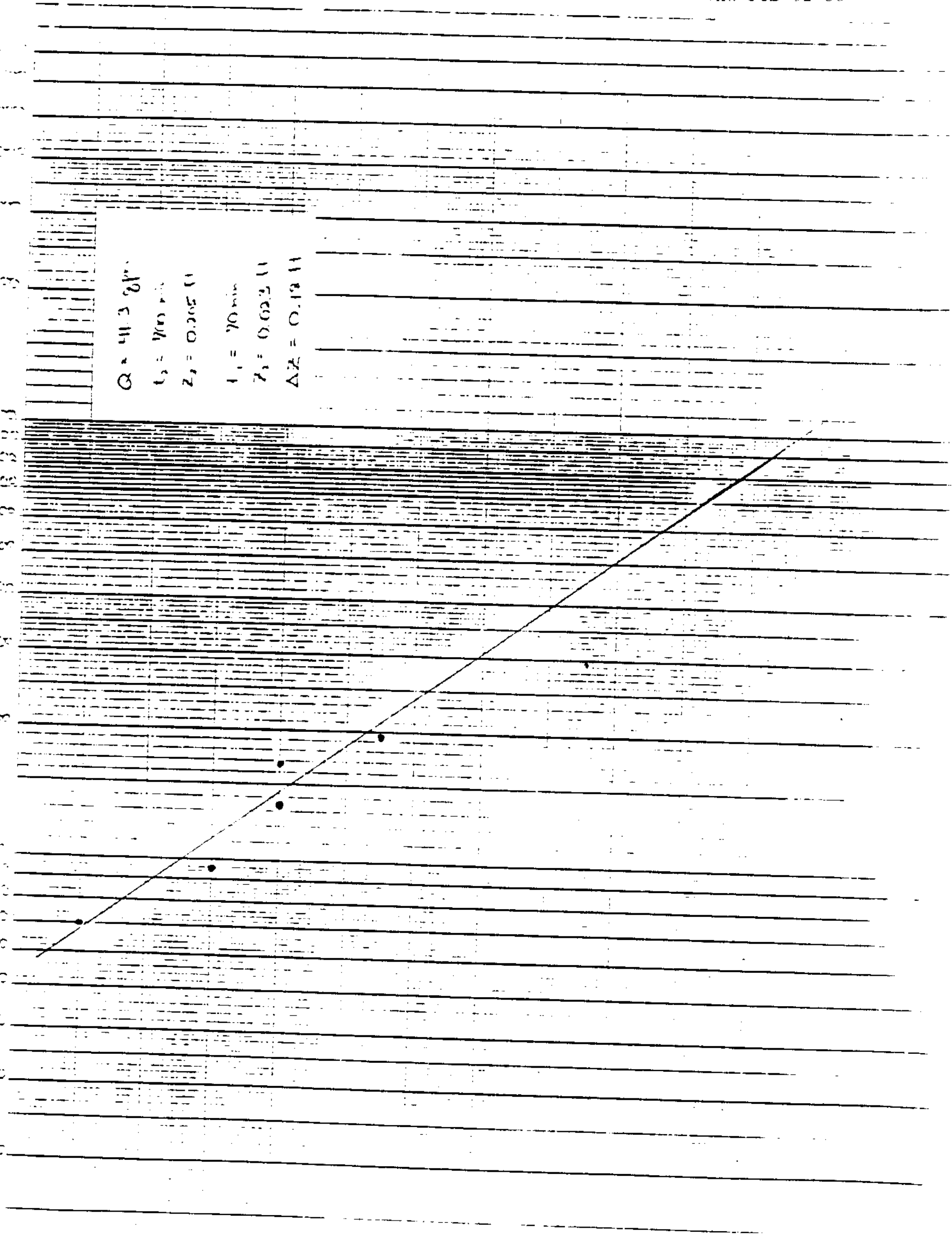
Pump Test Data

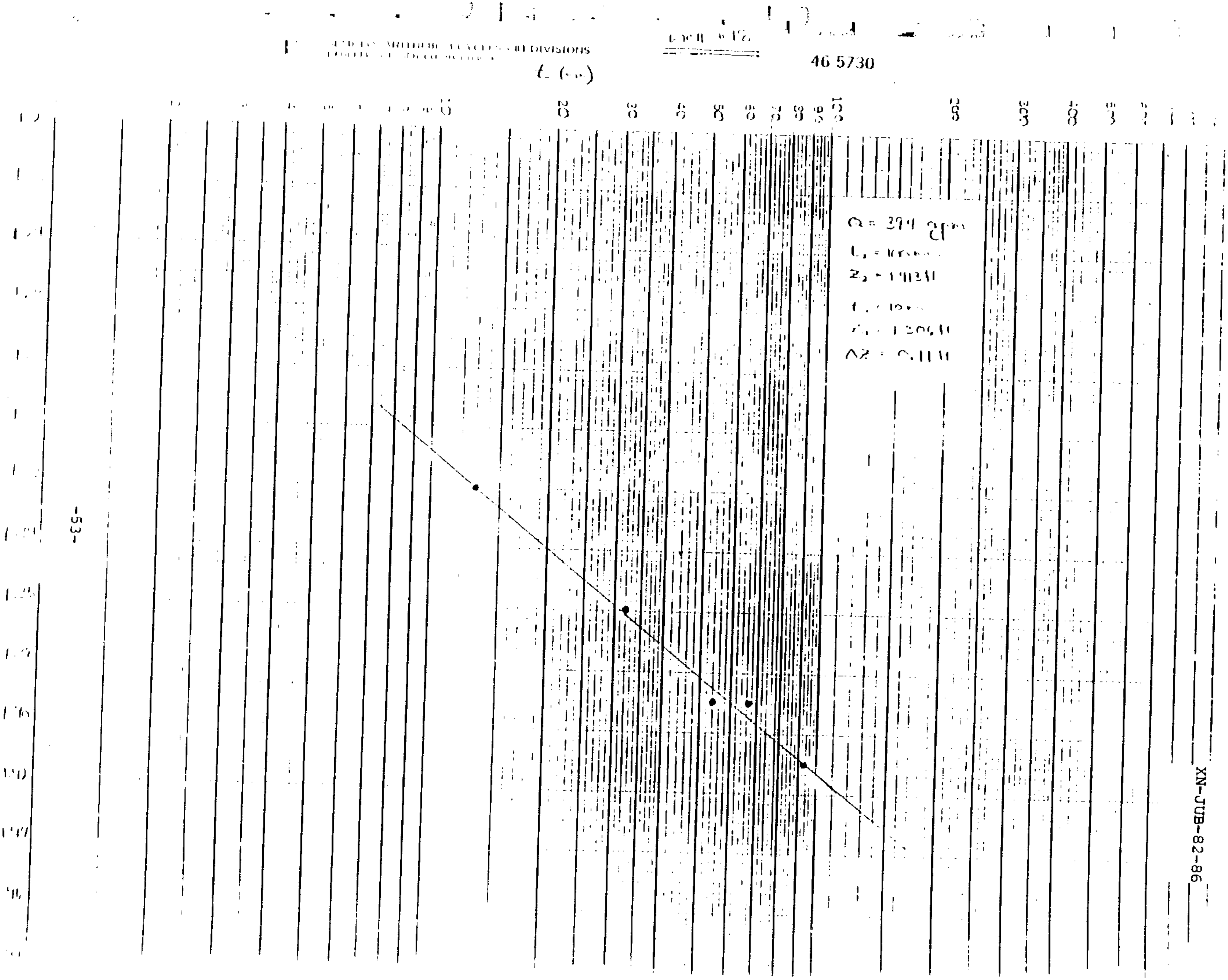
Well #17

Time (min)	Depth to Water (ft)	Drawdown (ft)
0	25.46	-
70	25.48	0.02
95	25.52	0.06
134	25.54	0.08
168	25.54	0.08
193	25.57	0.11

Well #18

Time (min)	Depth to Water (ft)	Drawdown (ft)
0	23.41	-
13	24.73	1.32
32	24.77	1.36
52	24.80	1.39
67	24.80	1.39
93	24.82	1.41


46 5730
t (min)
Q = 41.3 gpm
t_2 = 700 min
Z_2 = 0.205 ft
t_1 = 70 min
Z_1 = 0.023 ft
ΔZ = 0.18 ft


46 5730

Equations

(1) $\Delta Z = \frac{264\ Q}{T} \quad \text{Log}_{10}\ (t_2/t_1)$

(2) $T = \frac{264\ Q}{\Delta Z} \quad (\text{if: } t_2/t_1 = 10)$

(3) $P = T/M$

(4) $I = \frac{h_2 - h_1}{l}$

(5) $V = P * I$

Z = Drawdown (ft)
Q = Pumping rate (gpm)
t = Time since pumping started (min)
T = Transmissivity (gals/day/ft)
P = Permeability (gals/day/ft^2)
or (ft^3/day/ft^2)
or (ft/day)
M = Saturated thickness of aquifer (ft)
I = Hydraulic gradient (ft/ft)
h = Water level elevation (ft)
l = Distance (parallel to flow lines) between observed well levels (ft)
V = Velocity (ft/day)

Well #17 (1982)

Q = 41.3 gpm M = 20 ft
Z = 0.18 ft I = 0.00043 ft/ft
t_2 = 700 min
t_1 - 70 min

T = 60,573 (gallons/day/ft)
P = 3,029 (gallons/day/ft^2)
P = 405 (ft^3/day/ft^2)
P = 405 (ft/day)
V = 0.2 (ft/day)
V = 64 (ft/year)

Well #18 (1982)

Q = 39.4 gpd M = 20 ft
ΔZ = 0.11 ft I = 0.00043 ft/ft
t_2 = 100 min
t_1 = 10 min

T = 94,560 (gallons/day/ft)
P = 4,728 (gallons/day/ft^2)
P = 632 (ft^3/day/ft^2)
P = 632 (ft/day)
V = 0.3 (ft/day)
V = 99 (ft/year)

P (ave) = 3,900 gallons/day/ft^2
T (ave) = 77,567 gallons/day/ft
V (1977) = 72 ft/year (I = 0.00038)
V (1981) = 141 ft/year (I = 0.00074)
V (1982) = 82 ft/year (I = 0.00043)

High: 170 ft/year T = 94,560
I = 0.00074

Low: 56 ft/year T = 60,573
I = 0.00038

XN-JUB-82-86
Issue Date: 10/19/82

GROUNDWATER QUALITY AND FLOW CHARACTERISTICS
IN THE VICINITY OF THE EXXON NUCLEAR COMPANY, INC.
FUEL FABRICATION FACILITY

RICHLAND, WASHINGTON

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